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AGRICULTURE

THE SCIENCE AND PRACTICE OF BRITISH FARMING

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PREFACE TO SECOND EDITION

THIS book has been written with the intention of providing a convenient text for the use of students of agriculture. The present edition has been revised throughout, and a good deal of new matter added. In particular the results of several recent economic investigations have been embodied, a chapter on sugar beet has been added, and the sections on grassland and on animal nutrition have been in large measure rewritten.

The authors have to acknowledge with gratitude the helpful criticisms of many of their fellow teachers. They are indebted to the Agricultural Economics Research Institute, Oxford, and especially to Mr A. Bridges, for help in collecting economic data; to Mr Gibson and Dr Williamson of Edinburgh for assistance with Book I.; and to Miss G. M. Allchin of Oxford for valuable help with proof reading.

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AGRICULTURE

THE SCIENCE AND PRACTICE OF BRITISH FARMING

BOOK I

THE SOIL AND ITS MANAGEMENT

CHAPTER I

THE SOIL

The Formation of Soil.

Soil formation begins with the action of weathering, which includes all the processes that bring about the disintegration of the rocks. At first all rocks would be of an igneous nature because of their solidification from the liquid magma; but later on secondary rocks of sedimentary origin would be worn away by the same agency. An igneous rock consists of a mass of mineral crystals, each mineral having more or less distinct chemical composition and physical properties. Such rocks are comparatively stable so long as they are protected from weathering, but as soon as they are exposed on the surface of the earth they are subjected to chemical and physical actions which affect the different minerals to varying extents, destroying the crystalline cohesion as a whole, and ultimately reducing them, according to the susceptibility of their constituents, to coarse or fine particles of mineral matter. The chief agencies in this disintegration are the chemical and physical actions of the atmosphere and water, though to a less extent plants and animals have a share in rock-destruction, the former largely through the solvent and mechanical action of their roots and the latter by their burrowing and other activities.

The effects of air and water in denudation are best considered together. To begin with the action of the sun

brings about a constant transfer of water in the form of vapour from the surface of land and sea to the atmosphere, and in time saturation and low temperature cause the water to be precipitated in the form of rain, a great deal of which falls upon the rock surfaces. The action of falling water upon the rocks, especially when it is in the form of hail, is mechanically destructive to some extent, but this is little in comparison to its other effects. The rain water dissolves a portion of the oxygen and carbon dioxide of the air, becoming in fact a weak acid solution and oxidising agent, and its effect is to dissolve the basic substances in the rocks and remove them in solution, to oxidise, hydrate, and destroy other minerals, and in time to reduce the rocks to a rotten and friable consistency. This destructive effect is greatly facilitated by the rock's porosity—even the most dense stone having interstices accessible to moisture—because not only is the chemical action carried far below the surface, but the effect of freezing causes the water to expand and widen the inter-crystalline spaces. This makes room for more moisture which on freezing makes the pores again larger, finally disrupting the rock in every direction. Even a dry rock subjected to extremes of temperature will break down in time because of the internal stresses set up by the varying coefficients of expansion of its minerals. Again rocks are broken up to a great extent by the erosion of running water and moving ice. When the influence of all these agencies is considered, it can be easily understood how rocks in time gave rise to the fine mineral particles which form the basis of our typical soil. The story of soil formation does not end here, however, as it has to be explained why some soils are uniformly fine in texture while others are uniformly coarse and gravelly; why some soils resemble the rocks which they overlie while others differ from them in almost every character; and why the topography of the land varies so much from county to county.

In order to clear up the above points one must go back to the history of the earth's crust. Long after the original surface had solidified and cooled, and life had become

established, the crust continued to shrink in conformity with the diminishing temperature of its interior, and in so doing cracked, tipped, and overthrust in many places. These eruptions were accompanied by periods of violent volcanic activity: molten rock issued in streams from the fissures, overflowing previous lava flows, original and disintegrated rocks alike; ocean bottoms emerged from the sea and became continents only to sink below the tides once more, and for countless ages there was periodic instability; but denudation went on unintermittently. As cooling proceeded, however, the solid crust increased in thickness, violent plutonic disturbances became more and more rare, and at the present day volcanism is more or less quiescent. What became of the products of disintegration as they were formed? Some, no doubt, remained *in situ*, but enormous quantities were carried by running water from higher to lower levels; streams cut gorges from the mountains to the oceans, and as the young mountains of those days were very steep, the waters rushed with great velocity. Now the carrying power of water is proportional to its velocity and inversely proportional to the mass of its load, and the fast streams of those days would carry mineral matter ranging in size from the most minute rock particles to heavy boulders. It can be understood, then, that when a river entered the ocean and its velocity was checked, the heavier portions of its load were dropped almost at once and the lighter particles were carried out to sea as far as the current remained appreciable. In this way fan-light deposits were formed at the mouths of all the great rivers, consisting of beds of boulders and pebbles near the shore, coarse gravels and sands in the intermediate zone, and the finest silts farthest out to sea. What was the effect of this kind of erosion when it went on for thousands of years? The rivers, as long as they had sufficient velocity to carry sediment, continued to eat their way backwards into the high ground and wear away elevations; but when the land was reduced to a level so little above that of the sea that the rivers became sluggish, erosion came almost to a standstill, heavy rains produced floods which left alluvial

deposits along the river banks, and thus denudation and deposition came into equilibrium. Rivers with flood plains and meander belts therefore indicate that the topography is the result of many ages of weathering, while on the other hand high peaked mountains and rushing torrents point to comparatively recent upheaval.

Now if the bed of a sea that has become overlaid by the deposits of many rivers emerges from the ocean, the land which it forms will be composed of rocks totally different from the old volcanic sorts, and made up of innumerable superimposed layers of silt or gravel, consolidated by pressure, and often cemented by secondary minerals which have been carried to their interspaces by percolating water. Such rocks are termed sedimentary and are exemplified by sandstones and shales. The limestones and chalks are sedimentary rocks built up from the shells and skeletons of countless generations of lime-secreting organisms.

Practically every part of the earth has been submerged many times since the world began, every submersion being accompanied by a deposit of sedimentary rock, while the intervening periods of emersion were characterised by rapid denudation and weathering; and, to complicate matters still further, plutonic outbursts were continually intruding, engulfing, and superimposing the sediments with flows and bosses of igneous material. Another great factor in the modelling of the land surface was the periodic recurrence of epochs of intense cold during which great stretches of country were overlaid by ice-sheets and glaciers. As the glaciers moved with immense force, carving hills out of their way, widening gorges into valleys and paring away the upper strata of the rocks, they greatly modified the original landscape and carried masses of rock and mineral particles tens or hundreds of miles from their parent formations. Thus hundreds of square miles of our country became overlaid by a glacial mud consisting of a heterogeneous collection of rock-flour and boulders, and having no relationship to the local rocks: this deposit now forms the well-known till or boulder-clay.

The Constitution and Physical Properties of Soil.

The thickness of the soil may be no greater than a few inches as in the case of the chalk Downs, or, as in the case of an alluvial soil, a homogeneous material may extend to feet or even yards. The subsoil lies between the soil and the country rock; it is generally stony, coarse, and infertile, being in most ways intermediate between the productive upper layers and the barren rock below.

Now the texture and properties of any soil depend very largely on the size of the rock fragments of which it is composed and the nature of the organic and chemical substances which it contains. As the most important soil constituents are clay, sand, and humus, it is essential to know their special properties in some detail.

Clay.—Chemically, clay is for the most part a hydrated alumino-silicate; but ordinary clay is very impure and contains complex mixtures of all the finest fractions of the soil mineral matter. When clay in a wet condition is kneaded it becomes exceedingly close in texture and impervious to moisture, and when dried shrinks into a brick-like mass and retains its shape. If clay is rubbed up in a little water it breaks up into minute particles which remain almost indefinitely in suspension, but if a few drops of lime water are added the particles aggregate or "flocculate," settle, and the water clears. On the other hand, if a little nitrate of soda is added and the mixture shaken up, there is a tendency for the particles to separate or "deflocculate" and remain suspended. It is believed that these changes are due to part of the clay being in a colloidal condition, as all colloids exhibit the phenomenon of flocculation. It has been shown that these properties are lost if the clay is heated above a certain temperature. Another important characteristic associated with the colloidal condition of clay is its power of retaining certain manurial substances such as potash and ammonia, and preventing them from being washed away by percolating water.

Sand.—From the chemical point of view, sand consists

largely of small particles of quartz or silica, which are extremely resistant to weathering and solution, but small pieces of mica and other minerals are usually present; and in rare cases sands are almost pure calcium carbonate, being composed of sea-shells and littoral debris. The sand particles are relatively large in size and without cohesion, therefore sands drain and dry quickly and are easy to work. Sand has none of the properties of colloids and has little or no power to retain soluble manurial salts. Pure sand cannot support plant life and has practically no value as plant food.

Humus.—All soils contain a proportion of complex organic substances derived from plant and animal sources and in process of conversion by micro-organisms into simple soluble substances available for plant nutrition. This organic matter may be roughly divided into (1) material that has not yet decomposed and retains its cell structure, and (2) the dark coloured mixture of partly decomposed material and decomposition products to which the name humus rightly belongs.

The undecomposed organic matter has an important mechanical influence on the texture of the soil. When added to a heavy clay it opens it up, improves its aeration and drainage, and is in almost every way beneficial; but when it is added in quantity to soils of a light, sandy nature, it tends to increase the porosity of a material that is already too open for the best results, and until its decomposition is considerably advanced tends to hinder the rise of water from the subsoil and accentuates the action of drought.

The true humus, which consists of complex and little known products of the action of bacteria and fungi, has a far-reaching effect on soil texture and fertility. Owing to its black colour it produces a black or dark brown coloration in soils whenever it is present in considerable quantity (witness the black appearance of heavily dunged garden soils), and as black soils absorb more heat from the sun than light ones it tends to raise the soil temperature; moreover, it is continually undergoing decomposition which liberates nitrogen in a form

suitable for plant nutrition. Again, it has been shown that humus can withdraw various substances from their solutions, and it prevents ammonium, potassium, and other valuable manurial compounds from being washed to the drains. Humus has a great attraction for moisture and greatly increases the capacity of the soil to retain water, thereby decreasing the liability of the crop to drought. It binds the loose fragments of sands, imparting to them some of the desirable characteristics of clay, and yet improves the texture of a heavy soil and renders its cultivation more easy.

Soil Particles.—If a sample of soil is examined it will be found to consist largely of particles of mineral matter which vary greatly in size, and for the sake of convenience soil investigators have deemed it expedient to classify the particles according to their maximum and minimum dimensions, as shown in the following table :—

	Diameter of Particles in mm.
Stones and gravel	over 2·0
Fine gravel	2·0 to 1·0
Coarse sand	1·0 ,, 0·2
Fine sand	0·2 ,, 0·04
Silt	0·04 ,, 0·01
Fine silt	0·01 ,, 0·002
Clay	under 0·002

The above classification is of course purely arbitrary as there is no sharp distinction in size, composition, or physical properties between one group and the other, but an infinite series of gradations.

The true specific gravity of soil depends upon its mineral constituents, but as a rule it is about 2·6 and does not vary greatly, though it may be decreased if a high proportion of humus be present. But if a given volume of soil is removed and weighed, it will have an apparent specific gravity which depends on the volume of its interstitial spaces and is as a rule about 1·4. The weights of cubic feet of certain typical soils are shown in the following table, and it is interesting to note that clay, which is called "heavy" by farmers,

is actually lighter than the so-called "light" sand, its "heaviness" in reality consisting in its greater tenacity and resistance to cultivation.

Soil.	Weight of 1 cubic foot in lb.
Sand	90
Loam	74
Clay	64
Sandy-peat	49

When the specific gravity and the weight of a cubic foot of soil are known, it is possible to compute the volume of its pore space. Now the pore space depends on the way the soil particles are packed together, for it can be shown mathematically that if spheres of equal size are used, the volume of their interspaces can be varied from 25 to 50 per cent. by different arrangements in packing: this explains why soils can be compacted by pressure. Pore space is important because on it depends the maximum amount of water any soil can contain. From Table I. below it can be seen that

TABLE I.

	Weight of a cubic foot in lb.	Pore space per cent.
1st foot of soil	80	53
2nd ,,	93	44
3rd ,,	105	37

the subsoil is compact and contains a much smaller pore space than the well-stirred and aerated soil proper, while from Table II. it is clear that the smaller the particles the greater the interstitial volume.

TABLE II.

Nature of Soil.	Pore space per cent.
Clay	53
Loam	43
Sand	33

The capacity of a soil to retain water and soluble salts is largely proportional to the total surface of its particles, because it is partly surface tension that prevents water from percolating away; and again, as the solution of plant foods takes place at the surface, the greater the superficial area the more food will become available. The following table shows the vast difference that exists in the surfaces presented by sands and clays; practically it is less than the figures would indicate, because clay particles tend to aggregate under field conditions:—

Soil.	Surface in square feet per cubic foot of soil.
Clay . . .	174,000
Loam . . .	47,000
Sand . . .	11,000

Soil Moisture.—The soil may receive moisture directly from rain, or indirectly from its subsoil or from springs which are supplied by precipitations in other localities. It is also supplied from the atmosphere by condensation, for all solid bodies have a hygroscopic attraction, and it is in soils having the greatest surface area that this is most pronounced. Again certain salts have a deliquescent action and attract moisture from the air.

The amount of water a soil can contain is proportional to its pore space: under conditions of heavy rainfall it may become quite water-logged, and the superfluous water makes its escape by surface drainage; but under average conditions the water "percolates" through the soil under the influence of gravity until it reaches the water-table, which corresponds to the water-level in wells. Now the rate at which water percolates depends on the texture of the soil: when the soil is sandy and open the water gravitates very rapidly and the surface soon dries, but when the texture is close, as in a heavy clay, percolation is very slow and water frequently gathers in pools on the surface. Water which passes through the soil in this way goes to form a reserve

supply, and it is frequently useful in washing the soil free from plant poisons. However, it is disadvantageous in that it may wash soluble foodstuffs beyond the reach of plant roots, and may fill the pore space to such an extent that air is excluded and soil organisms are suffocated.

Percolation, however, can never completely free a soil from water, as a portion is held in the form of an elastic film adhering to the soil particles by surface tension. Surface tension is brought about by the attraction of the soil molecules for the molecules of water and is equal in all directions. If the soil is dried a little in one place, or its pore spaces are decreased in size by compaction, the surface tension is increased and water is attracted from damper regions where the tension is lower. The action of this force, which is also called "capillarity," is therefore to cause slow movements of water from wetter to drier portions of the soil, and to raise moisture from the water-table to the plant roots. Capillarity produces the only supply during periods of drought and between showers. The water moved in this way is not only the chief source of moisture for crops, but it also carries and distributes throughout the soil plant foods in solution; and as it never totally fills the pore space, it is always associated with a circulation of air. As is shown by the following table, the amount of water retained by surface tension depends on the texture of the soil and is greatest where the particles are small:—

	Percentage of Water retained by Surface Tension.
Sandy soil	5
Clay soil	33
Peaty soil	43

Soil can be dried to such an extent that surface tension is broken, and further evaporation causes it to become air dry; but it will still contain a proportion of hygroscopic moisture adhering to its rough surfaces, which, however, is not available to the plant. The amount of water held in this way varies in proportion to the surface of the soil

particles: it may be less than 2 per cent. in air dry sand or more than 40 per cent. in air dry peat.

Soil Temperature.—The usefulness of a soil is greatly influenced by its mean, maximum, and minimum temperatures. Most of the heat received by the soil comes from the sun, but it also has its temperature raised by conduction from the warm interior of the earth and by oxidation of organic matter. On the other hand, heat is continually being lost by radiation into space and dissipated by the evaporation of moisture. Now the amount of solar heat received by any soil depends on its latitude and elevation, being greatest near the equator where the heat rays are most concentrated, and at low elevations where dense and moist air bring about a maximum of heat retention. The aspect of the soil is also important because land facing the sun receives a greater concentration of heat rays, and in the northern hemisphere the soil temperature is always greatest on land sloping to the south. Colour, too, has an influence on heat absorbing power, and as light soils reflect much of the energy of the sun back into space, dark soils are always warmer. Now the amount of heat necessary to raise the temperature of dry soil by a given amount is less than that required to elevate the temperature of a similar quantity of water to the same degree, or, in other words, the specific heat of soil is less than that of water. It follows, therefore, that when heat rays fall on a mixture of soil and water, the greater the quantity of moisture present the less the rise in temperature, and peaty or clay soils with their high water content are cold and late. Again, the greatest amount of evaporation goes on in wet soils, and as water absorbs a great deal of heat in its change from the liquid to the gaseous state, soils having much moisture will be kept considerably cooler than those that are well drained and have an open texture.

Soil Types and their Characteristics.

It is the varying proportions of clay, sand, lime, and humus which give each soil its particular character, and accordingly soils are classified as follows:—

1. Clays.
2. Clay-loams.
3. Loams.
4. Sandy-loams.
5. Sands.
6. Peaty soils.
7. Calcareous soils.

1. **Clays.**—Soils that contain more than 30 per cent. of clay are usually called clay soils; they have most of the properties of pure clay but in a lesser degree. Clay soils cannot be worked when they are in a wet condition since they become puddled and impervious to water, dry into rock-like clods which cannot be reduced to the fineness required for a seed bed, and are rendered useless for the rest of the season. If the clay land is under grass it cannot be stocked in wet weather as treading "poaches" the surface, prevents the passage of air and moisture, and greatly deteriorates the herbage. It is therefore advisable to avoid deflocculation or puddling by every possible means. On the other hand, flocculation of clay brings about an aggregation of its particles. This gives it the texture of a coarse grained mass with all the advantages of large interspaces for the passage of air and the percolation of water. The clay-land farmer can best assist the flocculation and improve the condition of his soil by the liberal use of lime and of farmyard manure, and by ploughing early in the season so that the furrows are exposed to frost and weathering before an attempt is made to prepare a tilth; and of course it is of the utmost importance never to work such land until it has attained a certain degree of dryness.

On the whole, clay soils are rich, and when well handled in suitable seasons they are capable of growing splendid crops; but they tend to dry very slowly, and are difficult to drain; their coldness and wetness make them late, and their tenacity causes them to be difficult and costly to

work. They tend to crack in dry seasons, but because of their close texture they remain damp and their crops are not affected to any great extent by drought. Owing to their coldness and lack of air they tend to accumulate organic matter, and dressings of farmyard manure are very lasting. Clays have very large natural reserves of potash but may be poor in phosphates and sometimes in lime. Because of high labour costs, a great deal of our heavy land is permanently under grass. Typical clay-land crops are wheat, mangels, cabbages, and beans.

2. **Clay-loams.**—Clay-loams are intermediate in type between heavy clays and loamy soils.

3. **Loams.**—A loam contains from 8 to 15 per cent. of clay and may be considered the best all-round type of agricultural soil, capable of growing any crop. Its texture is such that it has most of the advantages of both clays and sands, yet none of their serious disadvantages. Owing to its high content of sand it is free working, well aerated, easily drained, and responds well to organic manures which soon decompose and become available for plant food. Its clay fraction, however, gives it a sufficiently fine texture to enable water to rise from the subsoil by capillarity, and it can withstand moderate periods of drought. Like clays, loams cannot be worked when they are in a wet condition, but as they are early and dry quickly they are in fit condition for tillage over much longer periods.

4. **Sandy-loams.**—Sandy-loams share the characteristics of the loams and the sands. They are not naturally rich but are very early, easily worked, easily drained, and respond to heavy dressings of manure. They are therefore greatly favoured by market gardeners who can afford to manure heavily and water if necessary.

5. **Sandy Soils.**—A sandy soil contains only about 5 per cent. of clay and is therefore composed of relatively large particles which make it open in texture and easily drained, but at the same time cause it to dry out rapidly during periods of drought. As sandy soils are so largely composed of practically indestructible fragments of mineral matter they

are exceptionally poor in plant foodstuffs and are often short of potash, phosphates, and lime. Under certain conditions sands accumulate organic matter, because in the absence of lime the decomposition of plant debris cannot proceed, and layers of peat may be formed; but under average field conditions where liming has taken place they are so well aerated that dung and plant remains decompose very rapidly. Sands are therefore generally called "hungry" soils. Because of their good natural drainage sandy soils are very dry, and consequently having a very low specific heat they warm up rapidly in the spring and produce very early crops. Again the risk of puddling these soils is so inconsiderable that they may be cultivated during all seasons, hence they are very suitable for forms of continuous cropping and market gardening. From the agricultural point of view pure sand is practically useless, most pure sands being allowed to lie waste, but it is possible to bring them into cultivation by claying, liming, and heavy manuring, a process which is too costly except where the land has a particular value due to the proximity of a ready market. By the use of organic fertilisers such as dung, by green manuring, and by consolidating with heavy rollers and the treading of sheep, the texture and water retaining power of sandy soils are greatly improved, and their fertility is enhanced. Because of their lack of tenacity and the ease with which implements work in them, sands are known as "light" soils. The crops best suited to light and sandy land are rye, turnips, carrots, and potatoes.

6. **Peaty Soils.**—There are many different kinds of peaty soil in this country, their worth depending to a great extent on the proportion of organic and mineral matter in their composition. Taking the extreme case of a deposit of peat or a peat-bog, one finds that the soil and subsoil are composed of an accumulation of plant debris, such accumulation only taking place under water-logged conditions where the absence of lime and air prevents natural decomposition. The plant remains are not, however, absolutely preserved, but are converted into true peat by certain organisms which work

in the absence of air. Such soils are practically pure humus, and compared to other soils are very nitrogenous. But so long as a bog remains in its natural condition it is useless for agriculture, and it is only by the expenditure of a large amount of capital that it can be made suitable for cropping. In the reclamation of a peat-bog the first step is to dig large open drains to carry off the water and to allow the land to settle, aerate, and dry; thereafter it may be made fertile by liberal dressings of sand and mineral manures, especially lime and potash. This means that to get a bog into cropping condition the soil has, in effect, to be manufactured, which in the absence of cheap labour is financially out of the question.

Another kind of peaty or black-mould soil is found in the Fen country. There the soil was formed in marshy river estuaries by a certain amount of silt and the debris of reeds and estuarine vegetation. Although Fen soils consist mostly of humus they contain a fair proportion of mineral matter, particularly lime brought by the rivers from the limestone formations in their basins. As much of the Fen land has been reclaimed by the draining of meres or lakes in recent times, the decomposition of the organic fraction, though proceeding actively, is still far from complete, and both soil and subsoil are still enormously rich in organic matter and nitrogen. Fen soils have a friable, dry, and sooty appearance and texture; they respond well to dressings of superphosphate, but they may be injured rather than fertilised by applications of dung and nitrogenous compounds, and consequently a system of farming has been evolved in which live stock plays no part. Although Fenland farmers can grow enormous crops, the quality of their produce is inferior and commands a second-grade price.

Peaty accumulations are also developed under average heavy land conditions when liming is neglected. For instance, many old grasslands have mossy turves many inches in thickness which show no signs of decomposition; they are inclined to sourness, and if the turf is ploughed in it rots very slowly unless lime is used to correct the soil acidity.

The crops most suitable to peaty soils are oats and potatoes, these being best able to withstand acid soil conditions.

7. **Calcareous Soils.**—Calcareous soils are open in nature and contain anything from about 5 to 50 per cent. of carbonate of lime. Soils of this type, as one might expect, are most common on the limestone formations where they are formed *in situ* by the action of weathering; but calcareous clays, or marls, are common as subsoils in many parts. Chalk and limestone lands have many disadvantages and have to be carefully and systematically farmed; in summer they are greatly affected by drought and bake into stony lumps; in winter they become soft and sticky, puff up under the influence of frost, and are apt to throw their crops out of the soil. Decomposition goes on with great rapidity in lime-rich soils, consequently it is difficult to keep them under cultivation and at the same time maintain an adequate supply of humus; it therefore becomes necessary to treat them very liberally with farmyard manure, and consume on the land by stock as many crops as possible. Thus we have the peculiar sheep farming of the Downs and the Wolds, where the animals are fed on a series of green crops and legumes so that they may consolidate the land and return in their excrement most of the organic matter to the soil. On most Down farms potash and super-phosphate are used for manuring the clovers and turnips respectively, and sulphate of ammonia is used as a nitrogenous fertiliser for the cereals. On the actual Downs the soils are so thin that they are left under grass, but in the valleys the soils may be deep and fertile and grow splendid crops of barley, lucerne, sainfoin and clover, and fair crops of turnips in favourable seasons. Soils rich in lime are very healthful for stock, and develop bone and constitution in young animals.

CHAPTER II

SOIL FERTILITY AND PLANT LIFE

In order to understand the requirements of plants it is necessary to be conversant with their mode of life, their growth, and their reproduction. While it is impossible to go into the details of plant morphology and physiology in this work, these points may be roughly outlined by considering the growth of a wheat plant. A grain of wheat consists of a germ or embryo plant associated with a reserve of food material, and when it is placed in damp, warm soil it swells by absorbing moisture, the embryo becomes activated into growth, and a shoot and roots are produced. The roots pass downwards and fix the plant; they have selective and absorbent power, and from the soil they obtain a weak solution of foodstuffs which supplies the tissues with salts and water. The first shoot develops into a green leaf which appears above the ground. Now a leaf is a specially modified structure which by means of its green colouring matter is capable of utilising the energy of the sun's rays to absorb carbon dioxide from the atmosphere and to convert it into carbon compounds suitable for nutrition and growth. Growth takes place by night as well as by day, the necessary energy being produced by a process of respiration similar to that which goes on in animals, resulting in the oxidation of carbohydrate material and the giving off of carbon dioxide and water. Oxygen is of course necessary for this process, which goes on not only in the leaves but in the stem and roots. Thus the plant gets its mineral matter and moisture from the soil, its carbon from the air, and its energy from the sunlight.

As development proceeds there is a translocation of synthesised carbohydrate and protein material from the

leaves to the growing points, and as the plant matures there is a general transference of nutrients from the leaves and stems to the seeds. Some plants form temporary food stores in their roots or tubers.

In addition to light, the conditions necessary for plant growth are: (1) a supply of foodstuffs; (2) water; (3) air; (4) a suitable temperature; and (5) the absence of any factor that may interfere with the functions of the protoplasm. All these requirements are equally important and if any one of them is unsatisfied the soil is to that extent infertile, and excess in one direction does not compensate for deficiency in another. The cultivator of the soil must be acquainted with the exact influence of these factors, as good farming consists of making good deficiencies and removing conditions that are harmful.

Plant Foodstuffs.—The most obvious way to learn what substances a plant obtains from its environment is to make an analysis of its tissues, and when this is done the following elements are found to be present:—carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium, sodium, sulphur, silicon, chlorine, and iron; but the presence of these substances does not necessarily mean that they are essential to the plant's existence. Carbon, hydrogen, oxygen, and nitrogen are obviously necessary for nutrition as the greater part of plant tissue is built up of their compounds; but in order to demonstrate the importance of the other elements, careful and elaborate cultural trials are necessary. By these means it can be shown that chlorine, sodium, and silicon, though often present in plant tissues, are unnecessary for their healthy growth.

The following is a brief account of the elements that are essential in plant nutrition:—

1. *Carbon.*—The greatest percentage of the dry matter of plants consists of carbon. It is mostly obtained from the carbon dioxide of the air by the process of carbon-fixation under the influence of sunlight, but some may be obtained by the absorption of carbon compounds from the soil. It has been demonstrated that growth can be

accelerated by increasing the concentration of carbon dioxide in the air about the plants, but this is not practicable on a field scale.

2. *Hydrogen.*—Hydrogen is found in all the plant tissues united to carbon and oxygen in the form of starch, sugar, oil, protein, etc. It is chiefly obtained from the water of the soil.

3. *Oxygen.*—There is almost as much of this element as of carbon in the dry matter of plants. It is obtained from the soil as a constituent of water, and in the form of compounds such as nitrates and phosphates. It is also obtained from the air in the process of respiration.

4. *Nitrogen.*—This is one of the most important elements in plant composition, as it is the essential constituent of all protein matter. With the exception of leguminous plants, which can obtain it from the atmosphere, it is mostly absorbed in the form of nitrates. Nitrogen is of very great agricultural significance, as in average soils the nitrogen content is so low as to act as a limiting factor to plant growth. To achieve the best results it is therefore almost universally necessary to add nitrogen to the soil as manure, either in an organic or inorganic form. In rare cases—for example in fen and peaty soils which are rich in organic matter—it is unnecessary to resort to nitrogenous manuring (see Nitrogenous manures).

5. *Phosphorus.*—This substance is usually absorbed by plants in the form of a phosphate of lime. It is a constituent of several kinds of protein compounds. Like nitrogen it is present in insufficient quantities in many soils, and, in addition to phosphorus applied in organic substances, large amounts are applied annually in the form of artificial fertilisers (see Phosphatic manures).

6. *Potassium.*—This element is an essential constituent of protoplasm and is present in the ash of all plants, being taken up from the soil in the form of nitrates, carbonates, etc. Many soils are deficient in potash and are improved by adding compounds of the element as manure (see Potassic manures).

7. *Calcium.*—Calcium is absorbed from the soil in the form of nitrates, sulphates, etc. It occurs largely in the leaf and stem, and in many plants combines with oxalic acid (an excess of which is harmful to the tissues) forming insoluble crystals and rendering the acid innocuous. Plants may grow for a short time without calcium but become weakened and stunted.

8. *Magnesium.*—Plants are dependent on the presence of this element, though its exact function is not clear; but it is found to the greatest extent in the seeds. An excess of magnesian salts is, however, harmful, and soils on magnesium formations may be infertile or barren. It is taken up by the roots chiefly in the form of carbonate.

9. *Sulphur.*—Sulphur is essential to the formation of certain protein compounds. It is required only in small quantities and is absorbed in the form of sulphate.

10. *Iron.*—The formation of the green colouring matter in plants is dependent on the presence of iron, though a very small quantity only is required. The presence of ferrous salts is detrimental to plant life.

Water.—Water is essential to the development of plants: it is required to form the tissues, gives rigidity to soft parts, and is the medium in which all foodstuffs are absorbed from the soil; its excess is given off by the leaves as vapour in the process of transpiration. In practice the water content of the soil is more often than anything else the limiting factor to plant growth, and the rate and amount of growth is proportional to the amount of water supplied until a point is reached when the water excludes air from the soil and a suffocating action is established. When well supplied with water crops tend to produce a large amount of leaf surface to cope with the transpiration which is necessarily large, and their growth is protracted. On the other hand, a shortage of water leads to the development of narrow leaves and large searching roots, and tend to induce early maturity. The amount of water transpired by plants for every pound of dry matter formed varies very widely and

depends largely on climatic conditions and the concentration of soluble salts in the soil.

Air.—The fertility of the soil is dependent on the entrance of fresh air to supply the roots and micro-organisms with oxygen and the nitrogen fixing bacteria with nitrogen. It should also be possible for the air to escape and so remove the excess of carbon dioxide liberated by decay and respiration. In all soils that are not water-logged this ventilation goes on naturally and is brought about by changes in the air pressure, the action of wind, the sucking action of moving soil water, and by expansion due to differences of temperature between the soil and the atmosphere. Oxygen and carbon dioxide are of course necessary for the life processes in the green parts of the plants.

Temperature.—Every crop has an optimum temperature for growth and ripening. At the same time there are maximum and minimum temperatures above and below which growth ceases, and a higher temperature still which is capable of killing plants and is known as their thermal death point. Taken on the average, farm crops do no grow when the temperature is below 41° F., but if the temperature is increased slowly the plants grow better and better until an optimum is reached about 80° F., after which growth takes place more slowly until it ceases at the maximum. When a plant is subjected to long periods of low temperature, it grows very slowly and assumes a purplish appearance, while, on the other hand, high temperature is apt to induce tall, lanky growth and weakness that renders the tissues liable to parasitic infestations.

Injurious Substances.—Under ordinary conditions of cultivation the most common substance which has an injurious influence on both the higher plants and the small soil organisms is the acid developed in the process of organic decay. This is found in largest quantity when decay takes place in the absence of air. Acid formed in this way must be neutralised by a basic substance, or it will cause the plants to be stunted and liable to disease. Acidity is due to the soil being poor in lime, and is increased by the use of acid artificial

manures that cause the lime reserve to be used up rapidly. The remedy is sufficiently clear—to dress the land with lime, to avoid the excessive use of acid fertilisers, and to keep the land drained and aerated. Traces of other acids, especially sulphur dioxide, are present in the atmosphere in the neighbourhood of many industrial centres: they do much harm to leaf tissues and cause the blackened, stunted growth so often seen on grass land in the vicinity of factories.

A great many substances are injurious when applied to the soil in excess; indeed valuable manurial salts may damage crops when applied in excessive quantities. Potatoes set on 10 to 15 cwt. of soluble manure per acre may be slow to come through the ground and stunted in their early growth owing to interference with their normal root action caused by high concentration of soluble substances in the soil water. Undiluted liquid manure has a "scorching" effect when distributed on grassland; large dressings of quicklime destroy the surface vegetation. But in all these cases exposure to weather and washing by rain restores the soil to its normal condition.

Metallic salts such as those of copper and ferrous iron are directly toxic in action, and gas lime, because of its sulphur compounds, is poisonous when freshly applied to the soil.

The formation of iron and plough pans has a mechanically injurious influence on plant growth, because these prevent the proper development of roots and interfere with aeration and drainage. They should be broken up by deep digging or subsoiling.

Soil Micro-organisms.

The natural vegetation which abounds on the surface of all fertile land is by no means the only soil flora. Indeed, as far as individual plants are concerned the surface vegetation forms but a small percentage of the total. The other plants are chiefly bacteria and fungi, mostly microscopic in size, and present in millions in every cubic inch of soil; their influence on fertility is of vital importance, for without them the

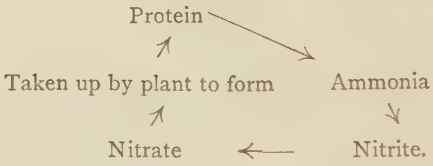
fundamental changes of a biochemical nature which make plant life possible, would cease. It is well then to consider in detail the most important actions which are brought about by bacteria, and on which the growth of the higher plants is absolutely dependent.

Decomposition of Organic Matter.—The decomposition of the remains of plants and animals in the soil is brought about by micro-organisms, but the nature of the decay depends on whether it goes on in the presence or absence of air. There are two great classes of soil organisms: (1) those that function in the absence of air, and (2) those that live and multiply in the presence of air. A good example of the work of the anaerobic organisms is the change that organic material undergoes in the formation of a peat-bog. It is the action of the aerobic bacteria, however, that has the greater significance for the agriculturist, since in well-aerated arable land anaerobic decay is essentially at a minimum. When dung, straw, leaves, and organic compounds are added to the soil they are oxidised through the action of the aerobic germs and disappear as if burned in a slow fire. The bulk of the non-nitrogenous material is broken down into water and carbon dioxide and the mineral matter is so simplified that it can be re-assimilated by higher plants. It is during this process that the very slowly decomposable substances known as humus are produced.

The decay of the nitrogenous material has the ultimate result of liberating the nitrogen in an inorganic form. In the first stage, which is known as putrefaction, micro-organisms change the proteins into such substances as peptones and amino acids. The next stage in the decomposition results in the liberation of ammonia and is consequently called ammonification. An example of this is the conversion of urea into carbon dioxide, ammonia, and water. The final stage in the process is known as nitrification. This consists of the oxidation of the ammonia, by a group of bacteria known as Nitrosomonas, to nitrous acid, which unites with a base, usually calcium. The nitrites are then attacked by another group of bacteria called Nitrobacter

and further oxidised to nitrates, which can be taken up by plant roots and used for building fresh tissues. The latter changes all take place very rapidly, and only the merest traces of ammonia and nitrites are ever found in the soil; but the first changes are slow and the rate of the transformation as a whole depends on the speed of ammonia production.

The everlasting cycle of changes brought about by putrefaction, ammonification, nitrification, and absorption, may be diagrammatically expressed as follows:—



However, the soil bacteria are only able to complete their work under the following conditions:—

1. The temperature must be suitable; the bacteria cannot work during periods of severe cold.

2. Air is required because some of the essential bacteria are inactive or absent in soils that are water-logged.

3. The organisms require the presence of a base to absorb the acids they produce, otherwise their activities are inhibited by the accumulation of their own products.

4. Sufficient moisture is required. All action is suspended if the soil be dry.

Losses of Nitrogen.—Denitrification is the term applied to a reducing process which goes on in the soil under certain conditions: it is the liberation of free nitrogen from nitrates. This change is brought about by another group of bacteria which are organic feeders and thrive in the absence of air; but as they must have oxygen they obtain it from oxidised inorganic nitrogen compounds so doing an infinite amount of harm by liberating the valuable nitrogen as gas. Denitrification is unlikely to take place unless large quantities

of unrotted manure and nitrates are present in a soil that contains very little air, and such conditions are uncommon in good agricultural practice. Therefore if care is taken to avoid the application together of long dung and nitrate fertilisers, little loss need be occasioned through this cause.

A more common action under conditions of poor aeration is for nitrates to be reduced to nitrites and ammonia, but this does not lead to loss of nitrogen.

It has, however, been repeatedly demonstrated that nitrogen can be lost under other conditions, though the cause has so far not been elucidated. In virgin prairie soils it is found that the nitrogen content remains fairly constant, and is naturally high, but it falls off with great rapidity as soon as arable cultivation is commenced, much more disappearing each season than is removed by the crop. Doubtless, whenever an old grassland is ploughed up in this country, a similar loss takes place, but nothing can be done to mitigate it.

Assimilation of Nitrogen Compounds.—Under ordinary soil conditions it is found that the addition of long dung or undecayed straw, which are rich in carbohydrates and have a high energy value, so stimulate soil bacteria that the organisms, in order to balance their nutrients, assimilate a large part of the available soil nitrogen and retain it in their body protoplasm. The effect on soil fertility is to subject the higher plants to nitrogen starvation, which, however, passes as the organisms die and their body nitrogen is liberated through the processes of decay. Green manures do not promote nitrogen assimilation because they contain sufficient easily decomposable nitrogen compounds to supply the demands of the bacteria that bring about their decay. In ripe straw the nitrogen compounds are decomposed only with extreme slowness.

Nitrogen Fixation.—(1) *Fixation by Symbiotic Organisms.* —It has been found that plants belonging to the natural order Leguminosæ can be grown without the addition of any nitrogenous manures in soil that is absolutely devoid of combined nitrogen—a circumstance that is extremely remarkable

in view of the fact that the leaves and seeds of the pulse crops contain more than twice the proportion of nitrogen found in the cereals. Leguminous plants may therefore be looked upon as accumulators of nitrogen while all the other cultivated plants are nitrogen consumers. It is necessary to state, however, that legumes grown under the above conditions exhibit a period of nitrogen starvation, which may last for a few days or a few weeks, shortly after germination; moreover, legumes are far from averse to dressings of nitrogenous manure and absorb nitrates readily, but after they have attained a certain degree of development they thrive perfectly without them. It is obvious that this type of plant must be able to obtain its nitrogen from the air, which contains ample nitrogen together with traces of ammonia, nitric and nitrous acids. But only free nitrogen is present in sufficient quantity to supply their needs, so they must be able to assimilate the free element and elaborate it into nitrogenous compounds.

Shortly after the above observations concerning the Leguminosæ had been made, attention was drawn to the occurrence of nodular swellings on their roots. At first these were thought to be the result of disease, but later it was concluded that they were normal growths, and finally it was discovered that their cells were packed with living bacteria. It was then shown that nodules did not develop on plants grown in sterile soil, and that under these conditions the legumes were unable to obtain atmospheric nitrogen, but when sliced-up nodules were added to the medium, the plant roots became infected by the bacteria, nodules were produced, and fixation of nitrogen commenced. These facts make it clear that legumes themselves are incapable of absorbing atmospheric nitrogen, but that this power is gained when certain bacteria are present in their roots.

The name *B. radicicola* has been given to the typical organism that is present in leguminous nodules, but it has been shown that this species consists of a large number of varieties. Bacteria obtained from one kind of leguminous plant grow most rapidly and produce the greatest number of

nodules when applied to plants of the same or an allied species. On some allied species they develop root-nodules to a lesser extent, and on totally dissimilar species they have no effect.

Strains of nodule bacteria have been shown to be interchangeable between the species in each of the following groups:—

1. Red clover (*Trifolium pratense*), Alsike (*T. hybridum*), Crimson clover (*T. incarnatum*), White clover (*T. repens*), and Meadow clover (*T. medium*).

2. Lucerne (*Medicago sativa*), Trefoil (*Medicago lupulina*), Sweet clovers (*Melilotus alba* and *M. officinalis*).

3. Garden and field peas (*Pisum sativum*), Vetch (*Vicia sativa*), Bean (*Faba vulgaris*).

4. French bean (*Phaseolus vulgaris*), Runner bean (*Phaseolus multiflorus*).

5. Lupines (*Lupinus albus, etc.*).

The association of the bacteria with the higher plants appears to be to their mutual advantage, and mutualism of this kind is known as symbiosis. Seemingly the bacteria derive their energy-yielding material from the plant juices, and build up their protein matter by fixing the free nitrogen of the air. The plants in turn derive nutrients from the bacteria.

The agricultural significance of the peculiar quality of Leguminosæ is far-reaching. It has been long known that the cultivation of legumes enriches the soil, and that the succeeding crops are benefited by the decomposition of the highly nitrogenous root substance; and practically every system of crop rotation includes a pulse or a clover. More recently legumes have been cultivated and ploughed in entirely because of their manurial value. It is found, however, that when land is newly reclaimed from marsh or bog, or has lain for generations under a particular kind of herbage, legumes may be unable to form root-nodules. This has been traced to the absence from the soil of suitable bacteria. Under these circumstances it may be advisable to inoculate with a suitable variety of *B. radicicola*.

Bacteriologists have prepared suitable cultures in which they recommend soaking the seed before sowing, but often the easiest method of introducing the desirable organisms is to obtain a quantity of soil from a field that has habitually carried the crop. By broadcasting this material with the seed sufficient bacteria to produce nodule formation are introduced.

(2) *Fixation by Other Organisms.*—Not only are soil organisms able to increase the nitrogen content of the soil by living in symbiosis with legumes, but other bacteria are able to use the nitrogen of the air for the formation of their body substance. The most effective of these organisms—*Azotobacter*—is found in practically all except acid soils. The vast stores of nitrogen in the unworked soils of the new countries, for example the prairies of Canada, are believed to have been accumulated largely through its action, but it only works well in soil well provided with carbonate of lime and phosphates. Azotobacter appears to live in the soil like an ordinary saprophyte, growing and reproducing rapidly when conditions are favourable, and dying off in millions at other times. When dead, the bacteria act like small pieces of organic manure, are decomposed by the putrefactive organisms, and become a source of food for higher plants.

In wet or badly aerated soils nitrogen fixation may be carried on to a very small extent by bacteria of the *B. amylobacter* group.

Soil Organisms.—The soil contains many organisms besides bacteria. It contains moulds and other fungi which have a considerable influence on organic decay; earth-worms which are beneficial, and insect grubs which may be parasitic and destructive; eelworms that are frequently harmful in attacking clover, corn, etc.; algæ that live like ordinary plants but are so small that they are not real competitors for food; and lastly, protozoa which are the simplest forms of animal life, feed upon bacteria, and have a considerable influence on soil fertility.

Soil Sterilisation.—Partial sterilisation of soil by means

of steam or volatile antiseptics is found in practice to lead to a greater production of plant food and a better and healthier development of the crop. The action destroys a large proportion of the soil organisms and is followed by a rapid multiplication of bacteria which have a beneficial effect on soil fertility.

Sterilisation has a practical application in gardening, particularly to the treatment of greenhouse soils, which, by heavy manuring, high temperature, and moist atmosphere become unduly susceptible to fungoid and amœboid infestations. Hence sterilisation by steam has become a common horticultural practice.

Soil Fertility.

Indications of Fertility.—A fertile soil must fulfil all the requirements necessary for plant growth. Wherefore it would seem that all that is necessary to gauge the value of any soil for agricultural purposes is an analysis of its constituents; but in practice this does not hold good, and it is only by growing crops on the land that its true worth can be ascertained. It is possible, however, to form an opinion of the fertility of any field by its appearance and the nature of the vegetation it is carrying. If land is covered with rushes, sedges, buttercups, and mossy growths, it is probably badly drained or even water-logged, whilst narrow leaved bluish-looking herbage and coniferous trees are indicative of water shortage. But when the vegetation is broad leaved, healthy looking, and spreading, and contains tall weeds such as fat-hen, the water supply is probably favourable and the land fairly rich. Sorrel, spurrey, and may-weed indicate that lime is short and the soil sourish. Colt's-foot is common on clays, couch grass on sands, and silver-weed on chalks. Large trees, healthy hedges, strong weeds, and bountiful crops are the best indications of good land; but the soil itself should be examined, as its warmth and earliness can be judged from its texture, and its humus content from its colour. The depth should also be ascertained, as the deeper the soil the greater its value; and the nature

of the subsoil has a considerable influence on its drainage and resistance to drought.

Loss of Fertility.—As crops grow they obtain large quantities of foodstuffs from the soil. If they are removed and the land is given either no manure or inappropriate manure, fertility is gradually lost. When a crop is grown for a series of years on unmanured land the yield during the first few seasons falls off rapidly, then more slowly, and finally a stage is reached when it remains practically constant. This means that fertility can be reduced by continuous cropping without manure, but not destroyed, the reason being that the actions of weathering agents and soil organisms are sufficient to liberate enough foodstuff each season to produce a small crop. Just as the growing and removal of unmanured crops reduce the fertility of land, so the rearing and sale of stock, and the production and sale of milk and cheese have a similar effect in reducing the fertility of the farm as a whole.

Now as fertility depends to a considerable extent on the soil texture, it can be reduced on wet soils by ploughing, by carting, by the use of heavy implements and by the treading of stock, all of which have a deflocculating action on clay. Further, certain manures—for example nitrate of soda—when applied for a number of years in heavy dressings have an injurious effect upon soil texture.

Another great source of loss consists in the "leaching" action of percolating water, which removes large quantities of soluble manurial substances. The greatest loss of this kind consists in the washing out of nitrates: large quantities of these substances are produced in a warm summer or autumn after the crops have been harvested. Nitrates are completely soluble and the soil having no power to retain them, they are carried away by the first autumnal rains which percolate down to the subsoil. Artificial fertilisers have to be purchased to make good their loss. Obviously, then, it is good farming practice to cultivate quick-growing catch crops at this time of the year, because when there is a crop to occupy the land, the nitrates are

absorbed and converted into protein matter. These crops can be ploughed in later in the year when the temperature is sufficiently low to prevent rapid organic decay, and the nitrogen compounds are preserved throughout the wettest part of the winter in an insoluble form. Lime, too, is continually being washed out the soil, and on average land should be replaced by liming at intervals. The soil, however, has power to retain quite a number of soluble manurial substances: it has been shown that organic compounds of nitrogen, ammonia and ammonium salts, phosphoric acid and potash are firmly held by interaction with certain soil compounds, whereas sodium, calcium, nitrates, sulphates, and chlorides are washed away at a rate proportional to the quantity and velocity of percolating water. (For the retention of manurial substances, see Manures.)

Other causes of loss in fertility are the liberation of gaseous nitrogen by fermentation, and the accumulation of weeds which absorb a large share of the nutrients intended for the crop, and compete with the cultivated plants for air and light.

Gain of Fertility.—The fertility of a farm is improved by the consumption of foodstuffs grown elsewhere, the application of purchased manures, the ploughing in of crops and crop residues, the work of the symbiotic and non-symbiotic nitrogen fixing bacteria, the natural weathering of soil particles, and the suppression of the weed flora. For improvement due to liming, manuring, draining, etc., the reader is referred to the subsequent chapters.

CHAPTER III

THE IMPROVEMENT OF THE SOIL

Drainage.

DRAINAGE is the practice of removing superfluous water from the soil in order to increase the fertility of the land. The need of drainage in any particular soil is exhibited by the surface being wet and spongy, by the presence of rushes, sedges, bent grass and other inferior, narrow leaved herbage, by the stunted and sickly appearance of growing crops, which may be drowned out altogether in the hollows, and by the presence of pools of water and of characteristic dark coloured, damp patches on cultivated fields.

The improvements brought about by drainage are manifold:—

(1) The soils are more easily and sooner worked. Undrained soils have a high specific heat, are slow to warm up in the spring, and owing to the risk of puddling cannot be subjected to the acts of tillage until the water has been removed by evaporation. The improved mechanical condition, higher temperature and earliness induced by drainage allow of a longer growing season, and early ripening. As seedtime and harvest are earlier, arable crops may be grown instead of grass, and fallowing may be superseded by green cropping.

(2) When the water is carried away from the surface layers of the soil, air enters the pore spaces and plant roots extend downwards. Thus the weathering of a fresh horizon of mineral matter is induced, the crops are able to absorb food from a greater surface, and the produce of the soil is improved as regards both quantity and quality. When pasture is drained the poor herbage gradually

disappears and is replaced by strong growing natural grasses of superior nutritive value.

(3) The beneficial action of micro-organisms is stimulated and there is consequently a more rapid liberation of plant food; lime and manures act better and more quickly; denitrification and its consequences are prevented. Many noxious insects and low forms of life harmful to the health of stock are got rid of as soon as surface dampness is removed.

(4) The percolation of water to the drains has a washing action on the soil particles so that poisonous substances, which tend to accumulate under water-logged conditions, are carried away, the formation of iron pan is prevented, and, in the case of a soil rich in alkaline substances, the efflorescence of injurious salts is stopped.

There are two common types of drains: (1) Open or surface drains. (2) Covered or deep drains, which function in the manner of underground water channels.

Open drains are used, to remove water from soils that are so impervious that the percolation of water to covered drains is impossible; in tidal districts and localities liable to flood, where covered drains silt up and are put out of action; in plantations and orchards where roots are apt to enter covered drains and obstruct the flow of water, and in certain systems of irrigation and sewage farming. The reason for the restricted use of open drains lies in their many disadvantages: they occupy a considerable area, interfere with cultivations and the use of heavy implements, harbour weeds and injurious pests, and are a continual source of expenditure if they are to be kept in good working condition.

Covered drainage or underdrainage is the system used for good arable land and its principles and practice must be considered in some detail.

Principles of Drainage.—At a certain horizon in or beneath every soil, ground water is found that completely fills the pore space. The upper limit of this zone of saturation forms a plane that is known as the water-table,

which, although it tends to follow the contour of the country, may be so far above the surface in places that it forms ponds, and so deep in other parts that it can only be reached by sinking wells. The level is lowered during periods of drought and raised during times of heavy rainfall; the water is continually being drawn down against the frictional resistance of the rock particles by the force of gravity, but is periodically replenished by precipitation and percolation. In hollows and places where there is no natural drainage the water-table reaches the surface and destroys the soil's fertility; in many soils, even when the permanent water-table is well below the surface, rains drain away by natural means so slowly that damage is effected; only on steep slopes and porous soils is natural gravitation sufficient to obviate all necessity for artificial drainage. The object of drainage is to offer a quick means of escape for water that is doing injury, and the depth and frequency of the drains are adjusted to limit the height of the water-table.

The distance between the drains is determined by the texture of the soil and the speed with which water percolates under the influence of gravity. Clay soils have a greater pore space than sands and consequently hold more water when saturated; but their particles are so small and their interstices so narrow that a great resistance is offered to the movement of water, and they drain much more slowly than soils which are coarse in texture. When drains are working in a wet soil the first portions of the surface to dry are those which overlie the lines of tiles, and the ground midway between the drains is the last to have its water-logged condition remedied. In other words, the water-table in the vicinity of the drains is lowered quickly, but between the drains it tends to remain at the surface for a longer period. This tendency is greatest where the texture of the soil is fine, and not only is percolation slow but high surface tension and capillarity have a counteracting influence on gravitation. Therefore in practice it is necessary in fine textured soils to place drains at close intervals, but in light

soils, where tiles "draw" for a greater distance, it is in the interest of economy to lay the drains farther apart.

The depth at which drains should be placed is intimately related to the distance between the lines of tiles. Because of the slowness with which percolation takes place in heavy land, drains will not act with sufficient rapidity unless they are placed comparatively near the surface, say $2\frac{1}{2}$ ft. Where deep draining has been practised under these conditions the results have been very unsatisfactory. On the other hand, drains may be placed at a greater depth in light soils; and because the deeper a drain is placed, provided that it works satisfactorily, the greater its "draw" and the fewer the number of tiles required for a given area, it is economical to place drains as deep as the texture of the soil will permit.

The following are the usual depths and intervals of draining practised in this country:—

Soil.	Depth in feet.	Intervals in feet.
Clay	$2\frac{1}{2}$ to 3	12 to 20
Medium loam . .	3 „ $3\frac{1}{2}$	20 „ 30
Sandy loam . . .	$3\frac{1}{2}$ „ 4	30 „ 40

The fall or gradient of the drains should be as much as conditions will allow, and the gradient for ordinary farm drainage should never be less than 1 ft. in 220 yards. The fall should be uniform, and on no account should a change be made from a steep to a less steep grade, because the check in the velocity of the running water will result in a deposition of silt which may choke the drain. If such a change is unavoidable a silt basin should be constructed at the junction of the two grades. A basin of this kind is a shallow well into which the water pours, is checked and deposits much of its sediment, and from which, at a point slightly below the in-flow, it passes out into the drain with the lesser gradient. The basin is covered to prevent accidents and the sediment is removed as often as is necessary. A large sewer tile, perforated for the affluent and effluent drains, placed vertically in the ground and covered over by a stone slab forms a cheap basin.

Drain tiles, either cylindrical or oval in section, made of hard-burnt clay, are now almost universally employed for field drainage. They should be very hard and should emit a clear ring when struck. Tiles that are dull sounding or contain lime are likely to be soft and are liable to crumble and cause the drains to collapse.

In considering the size of drain tiles it is necessary to divide drains into two classes: (1) Parallel Field Drains; (2) Main and Sub-main Drains.

(1) In the practice of field drainage it has been found that drain tiles less than $2\frac{1}{2}$ in. in internal diameter fail to give satisfactory service. Theoretically, a much smaller tile should suffice, but actually it is impossible to lay the tiles perfectly, and imperfect jointing and slight displacement so upset the working of small tiles that they choke up or fail to rid the soil of water. Indeed, many authorities maintain that it is inadvisable to use tiles less than 3 in. in diameter because slight errors in the grade cause them to fill with sediment. It has been pointed out that the interval between the drains does not depend on the carrying capacity of the tiles, but on the texture of the soil alone. One may take it, then, that the diameter of the parallel drains should not be less than $2\frac{1}{2}$ in. in a clay soil, where the intervals between the drains are least, or 3 in. in a sandy soil, and provided the drains are not more than 250 yards long and have at least a fall of 1 ft. in 220 yards they will be capable of removing the superfluous water from the soil, wherever the drains are placed at standard intervals, under any British climatic conditions.

(2) Mains and sub-mains are different. "Their size should be proportional to the rainfall, and the area and general slope of the land from which they receive drainage, without reference to the arrangement, number, or size of the laterals used in the system." The size of these tiles cannot be estimated exactly unless all the conditions under which the drain is to work are known, but they should be sufficiently large to remove in about forty hours the excess of water produced by the heaviest rainfall likely

to prevail locally. It is found that the size varies according to the area to be drained, the slope of the ground, the texture of the soil, and the resistance of the tiles to the flow of water.

The following table has been prepared from data collected by Elliot, and shows the acreage which different sized tiles may be expected to drain in clay and sandy soil under average farm conditions. The table is reckoned on the assumption of a 35-in. rainfall; if the annual precipitation is 25 in. the acreage should be multiplied by 1·4, and if 45 in. it should be multiplied by 0·7.

ACRES DRAINED BY TILE MAINS.

Nature of Soil.	Fall per 100 feet. Equivalent in inches.	Diameter of Tile in inches.					
		4	5	6	7	8	9
Clay . . .	2	8	12	19	28	42	61
Sand . . .	2	11	17	26	40	59	85
Clay . . .	3	10	16	23	35	53	78
Sand . . .	3	12	19	29	45	67	97
Clay . . .	6	14	22	33	51	74	108
Sand . . .	6	16	25	38	56	86	123
Clay . . .	9	17	26	40	63	92	133
Sand . . .	9	20	29	44	69	101	145

The Practice of Drainage.—The first thing to do in draining practice is to decide on the system that is to be constructed and the location of the drains. A drainage system consists of a series of parallel field drains discharging into mains or sub-mains, which in turn carry the water away to some natural waterway. The location of these drains must necessarily depend on the slope of the ground. In undulating land the main drains usually follow the principal hollows, the sub-mains the minor hollows, and the laterals are constructed either up or across the slopes according to the gradients. Fig. 1 illustrates two simple systems of drainage. In practice

however the best lay-out of the tiles must be decided in the field, and this is likely to involve the adoption and modification of several systems. Great care must be taken in choosing an outlet, the difficulty of securing a good discharge point being a frequent obstacle to field drainage.

Having decided on the most suitable system, the next thing is to fix the exact position of the lines of drains. This may necessitate the use of levelling instruments.

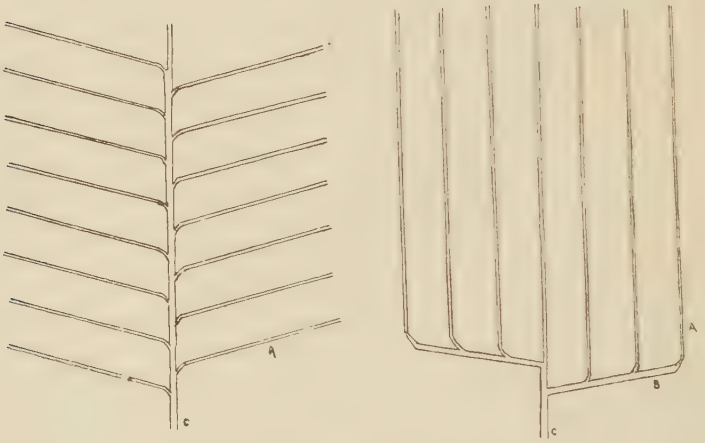


FIG. 1.—Arrangement of Drains.

A. Parallel or Lateral Drains. B. Sub-main Drains. C. Main Drains.

If the fall is very slight or obscure, most farmers would be well advised to call in the assistance of a surveyor, but if a good fall is assured and the system is not too elaborate, one should be able, by the occasional use of rough levelling devices such as boning rods and spirit levels, to carry out the whole of the work.[1]

When a field of uncertain slope is to be drained it should be divided into squares by driving pegs into the ground. A level survey should then be made and each peg marked

[1] For a full explanation of the use of levelling instruments, the reader is advised to consult one of the numerous text-books on Surveying.

with its own level. If the position and levels of the pegs are marked on an ordnance survey plan of the field, the slope will at once be apparent, and the location of the drains can be made accordingly. The next thing to do is to put in a series of pegs along the line of each drain to mark the gradient. For example, suppose a lateral is 10 chains long and the difference between its highest and lowest levels is 1 ft. 8 in., *i.e.*, it has a fall of 2 in. per chain. A peg should be driven into the soil at the top of the slope so that it protrudes 2 ft. above the surface, and, using a level and staff, another peg is driven at every chain down the slope so that the top of each peg is 2 in. below the level of the previous peg. A line along the tops of the pegs will represent the gradient of the drain.

When the location of the drains has been fixed, the drain tiles should be carted on to the land and laid down in convenient rows. The number of lineal yards of tiles per acre is got by dividing 4840 by the proposed interval in yards between the drains. A 10-yard interval would give 484 yards of tiles, and if each tile is 1 ft. long[1] the number required would be 1452. This number, however, must be increased by an allowance for breakages, and a sufficient number of tiles must also be obtained for the mains and sub-mains.

When the drains are to be excavated by hand, a cord is stretched on the ground to mark the true line of the trench, along which the drainer works with his shovels and ditching spades. The top of the excavation need not be more than 12 to 14 in. wide, and the trench is narrowed to the breadth of the tile at the bottom. Considerable economy may be effected by ploughing out the top layers of the soil, or, better still, by using a mechanical excavator to remove all the material down to the required depth.

When the trench is completed its bottom must be uniformly graded before the tiles are laid. To do this the drainer attaches a strong cord along the tops of the gradient pegs, supporting it if necessary and making sure

[1] Tiles are ordinarily made from 12 to 15 inches in length.

that it is practically straight. The pre-arranged depth at which the drain is to be placed + 2 ft. (the height of the datum gradient peg) will be the depth of the bottom of the drain at any point along the cord. Using an ⅂-shaped rod to take his measurements, the drainer carefully checks the depth of his trench, and, using his drain scoop, levels and grades the bottom until the fall is accurate and uniform.

The next part of the work is to lay the tiles, lowering them into position by means of a tile hook. The end of each lateral drain where it enters the main should be curved to form an angle of 30° to 45° with the larger drain, and should point in the direction of flow. Junction tiles undoubtedly give the most satisfactory and accurate jointing; but these are seldom obtainable, and although rough junctions may be made from ordinary tiles by chipping them with a hammer, the usual English practice is to lay the mains and sub-mains one tile's breadth below the level of the parallels, and to place the latter so that they discharge on to the top of the mains. A junction of this kind is packed with a few large stones, and although the flow is indirect, the water finds its way through the joints in the main and the results are quite satisfactory.

Great care must be taken in the construction of the discharge point of the main into the natural waterway. Glazed tiles only should be used at this point, as ordinary porous tiles are soon broken to pieces by the action of frost. The last tile should be cemented into a brick foundation which cannot be undermined by running water, and the end should be covered by a grating to prevent the entrance of vermin.

The ditches may be filled in by means of a spade, a plough, or a special soil scraper.

When the work has been completed, a survey of the drainage system should be drawn up and entered on the plan of the field. Such a plan will prove of immense value should it be necessary to trace a choked or displaced drain.

Mole Drainage.

With the exception of permanence, mole drainage has practically all the advantages of ordinary tile drainage, and is far less costly; but it can only be practised on soils which are heavy in texture and comparatively free from stones, and on land where a good fall is assured. Under suitable conditions the drains may last for twelve years or more, but on soils containing a small fraction of clay, or where the fall is poor, they cease to function properly after a much shorter time.

The drainage is performed by dragging a projectile-shaped iron "mole" fixed on the end of a strong knife-edged coulter, through the soil at a depth varying from 15 to 24 in. The mole is about 2½ to 3 in. in diameter and its passage forms an underground tunnel which serves to remove superfluous water. The walls of the tunnel do not readily collapse and the passage is kept clear by the action of running water.

The construction of mole ploughs varies considerably. The smaller implements, which can be worked by one of the heavier types of farm tractors, have frames like ordinary ploughs, very long slades, and guiding handles. The larger types have heavy frames mounted on wheels and can be worked to a greater depth: they are usually drawn by steam tackle of the winding-gear type.

Where shallow draining is being carried out, it is usual to run a mole every 3 or 4 yards, but when the depth is over 2 ft. the interval can be increased to 5 yards. In all cases where the land is laid up in ridges the drains run in the furrow bottoms. Where a very old system of tile drains is beginning to work unsatisfactorily, it is often preferable to proceed with mole drainage, at a lesser depth, than to carry out costly renovation.

With some types of implements the coulter can be drawn into the ground like an ordinary plough; with others it is necessary to dig holes in the ground into which the coulter is lowered to the required depth before the drain is com-

menced. In all cases the main drains must be constructed of brushwood or tiles, and the depth adjusted so that the discharge is received from the parallel mole drains. The mains may be laid either before or after the mole drainage is carried out.

Irrigation.

In this country the practice of irrigation is almost entirely confined to water meadows; but irrigation of a sort is also carried on for the disposal of sewage.

The most suitable waters for irrigation are those containing a proportion of lime and much sediment. When such are used the herbage not only receives all the water necessary for maximum growth, but a proportion of mineral matter as well. When a permanent irrigation system is prepared for grassland, the soil is underdrained with tiles, and a series of water channels and sluices prepared on the surface whereby water can be allowed to flood the whole of the vegetation. After flooding, the supply is cut off and the superfluous water finds its way to the drains. This treatment is repeated as often as is necessary. The plants thus receive an abundant supply of water, and a greatly increased yield per acre results.

Many towns have no suitable discharge point for their sewage, and are forced to cleanse it before allowing it to enter public waterways. One way of purifying sewage is to allow it to filter through a layer of soil, and when this method is adopted sewage farming is practised. Sewage farming can only be carried out satisfactorily on well-drained soil that has a free, open texture, *i.e.*, on land that allows of rapid percolation and bacterial action. On the farm, the sewage is brought through a system of pipes to sluices in the fields, and the land is prepared by digging channels and dykes which thoroughly spread the liquid over the soil. The sluices are kept continuously open for a month or more, when the soil becomes "sick" and the supply has to be turned on to fresh land. At this stage the soil is covered with a layer of black slime, but it soon dries and becomes ready for cropping. Needless to say, the organic matter

deposited in this way is a very valuable manure and produces luxuriant crops; but as it ultimately has a souring effect heavy liming must be associated with sewage farming. Sometimes the sewage can be used on a growing crop, *e.g.* cabbages on ridges, but in most cases the land is fallow while under treatment.

As the sewage has to be got rid of every day in the year, it follows that a large proportion of every sewage farm is carrying no crop; moreover, a very great deal of labour is required to prepare the land for the liquid. Consequently sewage farming is not as a rule a profitable business, but simply a means of ridding drainage water of its objectionable contents.

Warping.

The practice of warping consists of flooding land with water containing a large load of rich sediment in order to form a new layer of soil, and the source of supply is generally a muddy river. By means of lock gates the water is allowed to rush up channels and to flood the land quickly; the gates are closed and small sluices are opened which allow the water to escape slowly. The check in the velocity of the water brought about in this way causes a deposition of sediment. Near tidal rivers this treatment can be carried out daily, and in a few years two or three feet of extraordinarily rich alluvium are laid down. After this the warping is stopped, and the original channels are retained for drainage purposes. Before the War warping was extensively carried out along the banks of the river Trent. The cost was approximately £20 per acre for a 3-foot deposit of sediment.

Natural warps which occur along the banks of many rivers, have been formed during floods in the rainy seasons.

CHAPTER IV

MANURES AND MANURING

THE fertilising value of animal excrement, litter, and certain waste material has been known since man first cultivated the soil. As recently as last century the only known fertilisers were dung and lime, but in modern times researches in chemistry and plant physiology have lead to the introduction of a great many substances having manurial value, and the classification of fertilisers is now very complex.

As mentioned before, plants must be able to obtain ten elements if they are to exhibit healthy growth. Most of those elements are present in abundance in all soils, and manuring concerns only the addition of those that are so deficient that they act as limiting factors to plant development. It has been found by trial that the only elements in which deficiency occurs in ordinary soils are nitrogen, phosphorus, potassium, and calcium, and the science of manuring deals with the discovery of suitable compounds of these substances, their specific effects upon plant growth, and their most profitable methods of application.

Manures may be divided into particular and general fertilisers according to whether they supply one or more of the elements required by plants, or they may be divided into organic and inorganic fertilisers according to the nature of their origin.

It has been said that a fertile soil should contain 0·5 per cent. lime, 0·2 per cent. nitrogen, 0·2 per cent. potash, and 0·15 per cent. phosphoric acid, but so many factors influence the productiveness of land that no hard-and-fast rule can be laid down, and the most suitable manuring for any particular case must necessarily be found by actual trial.

The Nitrogenous Manures.

Nitrogen is the most important of all manurial substances, because its presence in the soil determines the yield of the crop more than either phosphates or potash; it is also the most costly, the most commonly deficient in quantity, and the most immediate in its effects; it is continually being depleted by washing to the drains.

The specific effect of nitrogen on plant growth is intimately connected with the development of leaf and stem. If the supply of nitrogen in the soil is deficient, the effect is seen not in a lesser proportion of nitrogen in the plant but in a general stunting of its growth, and in such cases the amount of other foodstuffs taken up from the soil depends on the quantity of nitrogen available. The markedly increased development of foliage due to nitrogenous manuring delays ripening, and the increased growth of straw in cereal crops renders them more liable to be laid.

Although in most cases the extra bulk developed by nitrogenous manuring is beneficial, there are times when crops are injured by being supplied with too much nitrogen. For example, nitrogenous manure is on the whole detrimental to the quality of malting barley, and excessive use of nitrogen in top dressing turnips, while adding little to the real value of the crop, makes it bulky and difficult to handle.

Nitrate of Soda.—The world's supplies of nitrate of soda are obtained from huge natural beds of soluble nitrates which have been preserved from the action of the weather by occurring in a rainless district of Northern Chile. The rock salts are mined and the nitrate of soda is obtained in a more or less pure state by solution and recrystallisation.

Commercial nitrate of soda contains 96 per cent. of sodium nitrate or 15·7 per cent. of nitrogen, which is equivalent to 19 per cent. of ammonia. The salt is in the form of rough granular crystals which vary somewhat in colour; it is deliquescent and if stored in a damp place becomes very wet. It tends also to become lumpy, and may need to be broken before it is in a fit condition for broad-

casting. It must not be mixed, unless it is to be sown immediately, with acid manures like superphosphate or dissolved bones, as in that case a loss of nitrogen will take place.

Nitrate of soda is quite soluble and is one of the quickest manures to act on the crop; but as it is soon washed down into the soil it favours plants of a deep rooting habit. It may to a small extent "burn" the crop by plasmolysing the tissues when it is first broadcast.

This manure is not retained by the soil, and as it is most easily washed to the drains and lost, it should never be applied in large quantities, nor should it be applied unless a growing crop is present to absorb it immediately. It interacts with clay and humus in the soil, and liberates a considerable quantity of potash which becomes available for plant food. It tends to deflocculate clay, and if frequently applied in heavy doses has a harmful effect upon the soil texture. This kind of deflocculation is ameliorated but slowly by the use of lime; it may be improved by the application of superphosphate or some such acid salt. Nitrate of soda acts as a base and has some effect in neutralising organic acids.

Sulphate of Ammonia.—In the combustion of naturally occurring carbonaceous compounds, a considerable quantity of ammonia is produced from the traces of nitrogenous matter which are always present, and in the manufacture of coal gas, the distillation of shale, and the heating of blast furnaces the ammonia is neutralised by passing it into sulphuric acid, and commercial sulphate of ammonia is formed. An enormous quantity is also made synthetically.

The commercial salt is 95 per cent. pure and contains 20·5 per cent. of nitrogen; it is in the form of small, elongated crystals that may be white or greyish in colour, and is marketed in bags. The bagged material tends to become lumpy, and may have to be broken before it is distributed, and because the crystals tend to pack together most machines have difficulty in spreading it. It usually contains a little free acid, but "neutral" supplies of 97 per cent. purity can be obtained which possess a first class

texture, and in which the acid has been reduced to a negligible quantity. Sulphate of ammonia must not be mixed with basic substances such as lime or basic slag, as nitrogen will in that case be lost.

Although sulphate of ammonia is soluble, its nitrogenous portion is firmly retained by the organic and mineral colloids of the soil; but the sulphate radical combines with lime and is ultimately washed to the drains as calcium sulphate. The ammonium compounds are oxidised to nitrates before they are taken up by the plants, and in the absence of a crop these nitrates are liable to be washed away. Sulphate of ammonia may be safely applied to land some time before the crop is in a position to absorb it, as a considerable time must elapse before it is nitrified, and it is only after nitrification that it is liable to be lost. In fact it is frequently applied with the seed, or it may be applied to autumn sown crops because the cold weather reduces the speed of nitrification, and the plants are able to absorb the nitrates as they are formed. As it is retained near the surface of the soil, it is most suitable for shallow rooted crops like turnips or barley.

As the acid portion of ammonium sulphate is washed to the drains in combination with calcium, this manure tends to deplete the soil of lime and in time makes the land sour. It should therefore be used with caution on soils that are poor in lime, but on the other hand it is the best nitrogenous fertiliser for chalks or marls. Its demand for lime is further accentuated by the fact that on nitrification it combines with lime to form calcium nitrate.

Nitrate of Lime.—This is a synthetic nitrogenous fertiliser prepared from the nitrogen of the air. In the manufacturing process atmospheric nitrogen is oxidised to nitric acid by the use of powerful electric arcs, the acid is neutralised by limestone, and the fertiliser obtained from the solution by crystallisation.

Commercial nitrate of lime contains about 75 per cent. of calcium nitrate or 13 per cent. of nitrogen; it is dark grey in colour and granular in texture, and because it is

deliquescent it is marketed in barrels or in special paper-lined bags. The manure should not be exposed to the air until it is required, as it tends to become so wet that it cannot be handled; it is apt to become sticky in the distributor and is a very messy substance to apply by hand. If possible a dry day should be chosen for its application.

As the manure is completely soluble it can at once be taken up by the crop, and is a valuable top dressing. As it is in the form of a soluble calcium salt it has a marked influence on soils which are poor in lime, and it usually produces better results under those conditions than either sulphate of ammonia or nitrate of soda. Its power of absorbing moisture from the air may be advantageous in allowing it to go into solution about the plant roots during periods of drought.

Nitrate of lime is not retained by the soil and should be used only as a dressing for growing crops. It improves the soil texture to some extent by the flocculating action of the lime that is left in the ground when the nitrate is absorbed.

Calcium Cyanamide is a synthetic fertiliser prepared by heating calcium carbide in a current of pure nitrogen. It is prepared in countries where cheap electrical power can be obtained from natural sources.

The commercial manure is little more than half pure and it is guaranteed to contain 18 to 20 per cent. nitrogen. The remaining portion is largely made up of quicklime and carbon. The fertiliser is a fine, dark-coloured powder having the appearance of basic slag, but is lighter in weight and smells slightly of ammonia. Because of its high content of lime it tends to absorb moisture from the atmosphere. It should be stored compactly as it also tends to lose ammonia at its surface. It is so fine and dusty that it floats in the air, is difficult to sow, and finds its way into the mouths, noses, etc., of the workers; the early attempts to give it a granular texture met with little success. At the present time supplies of nitrolim of improved texture are obtainable, and the standard nitrogen content is 19 per cent.

Calcium cyanamide is quite insoluble, but when added to the soil decomposes into calcium carbonate and ammonia. It is slower of action than sulphate of ammonia, and under certain conditions is believed to be injurious to delicate seedlings. It should therefore be applied shortly before seeding and harrowed into the soil, so that it decomposes to some extent before the young shoots develop. Although it is not washed out of the soil it has been found that under average conditions it is about 10 per cent. less valuable than nitrate of soda; but its high content of lime gives it a particular value for soils that tend to be sour.

A number of British-made nitrogenous fertilisers are likely to be placed on the market before long. For example, ammonium chloride has been prepared synthetically from the air and tried successfully on a number of crops. It contains 25 per cent. nitrogen, has a snow-white crystalline texture, spreads easily, and behaves in the soil in a manner similar to sulphate of ammonia. Urea and ammonium nitrate are also likely to be used in the near future.

The Phosphatic Manures.

Phosphorus is essential to the growth of all plants, and is taken up from the soil in the form of soluble phosphates. A great number of soils, particularly clays, are poor in phosphates, and the addition of phosphatic fertilisers is necessary on all land where intensive systems of farming are practised.

Phosphorus is a constituent of a large class of vegetable proteins, and its effects on the plant seem to be associated with cell division; it occurs in greatest quantity in the reproductive parts, and almost twice as much is found in the grain as in the straw. It promotes rapid root development, early maturity and ripening; it stimulates the development of young seedlings and has a particular influence on shallow rooted plants which have a short period of growth. Phosphatic fertilisers are most largely used for root crops and barley, and for the improvement of the feeding value and quality of grassland: they are obtained from both organic and mineral sources.

Phosphates are firmly retained by ordinary soils, and phosphorus is not found in the drainage water. Many of the manures are insoluble and are only rendered available for plant food by the slow process of weathering. When soluble compounds of phosphoric acid are applied they unite with basic substances, become insoluble, and cannot be washed away.

Bones. — Bones are composed of calcium phosphate, calcium carbonate, fat, and nitrogenous matter. Bones were first prepared for application to the land by crushing them into rough lumps in a grinding mill, but they are now sent to factories for extraction of their valuable fat and gelatine, and the residues only are converted into fertiliser.

Bone meal is a coarse form of crushed bones containing about 49 per cent. of calcium phosphate, and 3 to 5 per cent. of nitrogen. The nitrogen is contained in the cartilaginous matter and is slow to decompose; indeed the whole of the plant food in the meal is liberated gradually and continuously, but this gives it a particular value for light-land farmers. It is unsuitable for heavy soil.

Steamed bone flour contains about 60 per cent. calcium phosphate and from $\frac{3}{4}$ to $1\frac{1}{2}$ per cent. of nitrogen: it is prepared by grinding bones which have had their cartilage extracted and has a much finer texture than bone meal. The flour is so light that it is best applied in mixture with other fertilisers, and it is often included as a drier in compound manures. It gives very good results when applied to light land, its rate of decomposition being intermediate between those of bone meal and superphosphate, but it is better than superphosphate for soils poor in lime.

Dissolved bones contain about 33 per cent. of calcium phosphate and 3 per cent. of nitrogen. They are prepared by treating the bones with sulphuric acid to increase the solubility of the phosphates, and can be used on all soils in place of superphosphate.

Superphosphate.—This is the most largely used phosphatic fertiliser. It is prepared by treating naturally occurring mineral phosphates with sulphuric acid in order to render them soluble, easily distributed through the soil, and available

for plant nutrition. It is a grey friable powder and is marketed in different grades which are guaranteed to contain 26, 28, 30, 35, or 38 per cent. of "soluble phosphate," but it also contains a considerable amount of calcium sulphate and a small amount of unaltered tricalcic phosphate. When the manure is kept for a considerable period it tends to revert to insoluble phosphate and always reverts when it is applied to the soil; but as it is well distributed before reversion takes place, it is the most readily available and quickest acting form of phosphatic fertiliser. It is wasteful to use superphosphate on sour soil because the latter contains soluble iron and aluminium salts which unite with and precipitate the fertiliser in such a stable form that it is practically no longer available for plant nutrition. When superphosphate is first applied to the soil it produces an acid reaction, but, contrary to popular belief, it has no permanent effect in increasing soil acidity. A drawback to the fertiliser is that it may encourage club-root disease in cruciferous crops.

Basic Slag.—Basic slag is a by-product in the manufacture of steel; it contains a varying proportion of phosphoric acid, which is probably combined in a complex manner with silica and lime. The slag is rendered suitable as a fertiliser by grinding it to a fine powder between steel rollers, and at least 80 per cent. of it should pass through a sieve containing 10,000 meshes per square inch. The value of slag is judged by its fineness, its percentage of phosphoric acid, and its solubility in a standard solution of citric acid—made up to be somewhat comparable to soil acid—but recent investigations tend to show that its citric solubility is of varying importance according to the nature of the soil.

There are three classes of basic slags, obtained from different manufacturing processes, which differ considerably in properties:

1. Bessemer slag produced when steel is made by the Bessemer process. It contains an equivalent of 40 per cent. calcium phosphate (about 80 per cent. of which is citric

soluble) and is the richest and most valuable form of slag. Bessemer slag was very largely used before the War, but very little is now placed on the market.

2. Open hearth slag which contains an equivalent of 15 to 31 per cent. of calcium phosphate, and is soluble to the extent of about 80 per cent. in citric acid. This slag is inferior to Bessemer slag only in that it is more bulky and costly to handle.

3. Open hearth slag made with the addition of fluorspar, which greatly reduces its citric solubility. It is produced by the most modern process, contains phosphoric acid equivalent to about 15 to 20 per cent. calcium phosphate, and is about 20 per cent. soluble in citric acid.

Basic slags are insoluble in water but when added to the soil are dissolved by weak carbonic acid. The poorer qualities are rendered available more slowly and should be applied some considerable time before the crops are to be grown. Rich slags, however, produce beneficial results almost immediately. Although the phosphoric acid content is most important, slag contains also a small amount of lime, a combination which produces phenomenally good results on grassland by developing the clovers and indirectly bringing about an accumulation of nitrogen which benefits the other herbage. The best results are obtained when slag is applied to damp, heavy land. On light land and under dry conditions it may be inferior to a mixture of superphosphate and lime.

Mineral Phosphate.—Rock phosphates, varying in purity and hardness, are found in beds in various parts of the world and form our chief source of phosphoric acid. For example, the following phosphates have been used largely in this country for agricultural purposes:—

South Carolina phosphate	containing	about	60	per cent. tricalcic phosphate.
Ephos (African)	„	„	65	„
Florida . .	„	„	66	„
Gafsa (African) .	„	„	57	„
Nauru (Ocean Island)	„	„	86	„
Tunisian .	„	„	55	„

It has already been pointed out that rock phosphates are used in the manufacture of superphosphates. Increasingly large quantities are, however, being finely ground and used directly as a fertiliser, particularly for grassland. The fineness of grinding is very important and better results are obtained when the material is crushed so that it will pass through a screen with 14,400 holes to the square inch (120 mesh sieve) than when a 100 mesh sieve is employed. The fertiliser does best when employed on acid soils and in wet localities, the reason being that the wetness and the acidity cause the insoluble tricalcic phosphate to become more quickly available. It is best to apply the phosphates some time before they are required to act, and it is unlikely that they will have much effect on a crop such as barley, which has a short growing season. Mineral phosphates usually contain from 10 to 20 per cent. of calcium carbonate.

The Potassic Manures.

Potash is widely distributed and occurs in association with the clay fraction of all soils, but it may be deficient in soils of a sandy nature. Even on rich soils, however, the potash may not be sufficiently available to supply the needs of crops like potatoes and mangels, which store up large quantities of carbohydrate material. In such cases soluble potash manures may be profitably applied.

The effect of potash on the plant is to produce tone and vigour, and in unsuitable seasons potash-starved plants are the first to succumb to bad weather and disease. Potash seems to be associated with the process of carbon assimilation, for when it is deficient the formation of starch, sugar, etc., is greatly reduced; it has a distinct effect on the weight of individual cereal grains (a quality possessed by neither phosphates nor nitrogen) and is useful in producing a plump, bold sample in a crop like barley. It has a useful effect in stiffening straw, and may prevent crops from being laid in bad seasons. Potash, when applied to clovers and other legumes, brings about a remarkable improvement which

may be partly associated with its stimulation of nodule bacteria.

When excessive quantities of potash manures are added to heavy land the texture may be injured, because a proportion of potassium carbonate is formed, and this substance has a deflocculating action on clay. Although all the manurial salts are soluble, they are firmly retained in the soil by interaction with humus and the fine colloidal portions of the clay, and potash may be applied at any season of the year without fear of loss.

The first potash to be used for soil fertilisation was obtained by burning wood, seaweed, and organic residues, but supply from these sources being limited, it was not used on a large scale until deposits of potash salts were discovered in Germany. The working of the German mines commenced in 1861, and before the War they supplied the world with about ten million tons per annum. When the supply was cut off during the War the scarcity of potash was very severely felt, and it was necessary to elaborate processes for its extraction from wool grease, felspar rock, seaweed, and various forms of ash. Since the War, Alsatian deposits, which had been discovered in 1904 when boring for petroleum, have been worked on a large scale, and French potash is now being marketed in competition with the German product. The material from both sources is sold either as refined salts of potash or as a mixture of crude, crushed material graded to contain a given percentage of potassium.

The following are the potash manures at present on the market:—

Kainit	containing	14	and	20	per cent. of potash
Potash salts	„	20	„	„	
Potash salts	„	30	„	„	
Sylvinit	„	30	„	„	
Muriate of potash	„	50	„	„	
Sulphate of potash	„	48·6	„	„	

As a rule, potatoes and young seedling crops are most benefited by the sulphate and muriate, which can be safely

applied at setting or seedtime. Kainit and low grade potash salts contain a large admixture of common salt and other impurities, and should be applied to the land several months before the crop is to be sown so that the impurities may be washed away by percolating water, otherwise they may be injurious to sprouting seeds and tubers. The crude salts are generally cheapest per unit of potash, and are most suitable for grassland and mangels.

The colour of the potassic fertilisers is very variable, and the pure salts may be either crystalline or powdered, but they are all easy to spread; they may be stored for any period without loss, though in time they become somewhat lumpy and may have to be broken up before distribution.

The General Manures.

Farmyard Manure.—Farmyard manure is the best all-round soil fertiliser. It does not enter into competition with the artificial manures, but should be used in conjunction with them, and practical farmers agree that its value is greater than can be assessed by the consideration of its analysis. Not only does it supply to a greater or less extent all the plant foods that are likely to be deficient in agricultural land, but it improves the texture and tilth of the soil, increases its capacity to hold water, and encourages the biochemical actions which are essential to plant life.

Dung consists of a mixture of the litter and excreta of different kinds of stock, and is therefore made up of straw in a fresh condition, fæcal matter that has resisted the action of digestion, and urine which is a solution of substances that have been absorbed from the food into the blood and finally excreted from the system. Urine contains about half of the nitrogen and most of the potash voided by the animal; it is the richest, most important, and most easily lost portion of the manure. The solid portion of the dung contains the other half of the nitrogen, which is in a form slow to decompose, and most of the phosphoric acid and lime of the food. The composition of "made"

dung is very variable, but on an average 1 ton of farmyard manure contains 12 lb. of nitrogen, 5 lb. of phosphoric acid, and 12 lb. of potash. The quality of dung is influenced by a number of factors which are considered in some detail below:—

1. *The Food of the Stock.*—With ruminants and horses on ordinary rations about half of the dry matter fed is returned in the manure, the remaining portion being built up into the animals' tissues or destroyed by respiration and fermentation in the production of heat and other forms of energy. With pigs, which are ordinarily fed on more highly digestible foods, the proportion of dry matter that reappears in the manure is less. As the oil and starch contents of the food have no influence on the value of the manure, only the nitrogen and ash in the animal's diet require consideration. Cakes and leguminous foods are rich in all the valuable manurial constituents and produce rich dung that ferments readily; cereal grains and hay produce manure of average richness, while turnips and straw give rise to a substance that is somewhat poor in quality and ferments but slowly.

2. *The Litter.*—The chief value of litter is its power of absorbing moisture and volatile decomposition products. The ordinary cereal straws form the most common litter of the farm: they should be used unsparingly if loss of urine and ammonia is to be avoided, and they decompose readily in the field with the liberation of plant foodstuffs. A ton of straw will generally soak up enough moisture and retain enough fæcal matter to form from 4 to 6 tons of fresh manure. Moss litter is much superior to straw in its power of absorption, but is slow to decay and less suitable for improving the texture of heavy land. When bracken is available it forms excellent litter, for although it does not wear as well as straw it is richer in potash.

3. *The Age of the Animals.*—Young growing animals absorb a great deal of the nitrogen and ash of their food to build up muscle and bone, and may return less than half to the manure heap in their excrement. On the other

hand, when well-grown animals are being fattened their live weight increase is associated almost entirely with the development of fat, which contains no manurial substance, and is therefore formed without loss to the manure. Indeed, fattening bullocks may remove less than 5 per cent. of the nitrogen and ash from their food.

4. *The Kind of Animal.*—Horses produce manure of a rich, dry nature; it is called "hot" as it ferments rapidly and does not last long. It should be well mixed with litter or other dung as it tends to lose its nitrogen quickly in the form of ammonia. Cow's manure is of a very watery nature; it is "cold," *i.e.* decomposes very slowly. The manure obtained from cows may be likened to that of young stock, because in the production of milk and the development of the unborn calf a great deal of nitrogen and mineral matter is extracted from the food and never finds its way to the dung heap. Cows produce a great bulk of urine, and as litter is seldom available in large quantities on a dairy farm it is particularly desirable to construct a tank for the preservation of the fluid, which can be removed periodically and distributed over the pastures. The excrement of bullocks is superior to that of cows, the best being obtained from fattening beasts. The manure of pigs resembles cow dung in being cold and slow to ferment, while sheep's excrement is concentrated and rots freely.

5. *The Method of Making and Storing.*—It is generally impracticable and often undesirable to manure crops with fresh excrement and litter. The dung has usually to be stored for considerable periods, and during this time it rots until it has the desirable texture of "made" manure, losing much of its carbonaceous matter by fermentation and oxidation. Unfortunately these changes are always accompanied by the loss of a considerable portion of the most active and valuable nitrogenous substance of the urine. Although this cannot altogether be obviated it is to the interest of the farmer to reduce it to an absolute minimum.

What is the nature of the decomposition which goes on in the manure heap? The most obvious change is the alteration

of the straw, etc., into brown structureless humus. This decomposition is due to the action of bacteria under mixed aerobic and anaerobic conditions, and results in the loss of at least 25 per cent. of the dry matter of the manure. The loss of non-nitrogenous organic matter is of little importance, but the loss of nitrogen is serious and extremely costly. Dung contains the nitrogen of the straw, the nitrogen of the fæces which has resisted the process of digestion, and the soluble nitrogenous compounds of the liquid excrement. Investigations have shown that it is the nitrogen of the urine only that is liable to be lost. When urea ferments it is converted into ammonium carbonate, which in turn may decompose with the liberation of ammonia, and even of free nitrogen. Now it has been shown that litter is capable of "fixing" a certain proportion of this ammonia in a stable non-ammoniacal form, but cannot hold more than 0·72 part of nitrogen per 100 of dry straw. A further quantity of ammonia is retained by physical means when the dung is in a well-preserved, moist condition, but is entirely lost when the manure is dried. It would seem, then, that the ammoniacal nitrogen is so liable to be lost in the carting and spreading of the dung that it is desirable to have as much as possible in the stable state. This can be brought about only by using sufficient litter to fix the whole of the nitrogenous matter in the urine.

From the above it will be gathered that in systems of farming where bullocks are looked upon as a means of converting straw into manure, it is more profitable to keep a limited number of animals and to supply them with ample litter than to attempt to increase the quality of the manure by heavy stocking and liberal cake feeding. But under most farm conditions the stock is as important as the crops and only a limited quantity of litter is available.

Farmyard manure that has undergone a minimum loss of dry matter produces the best results when applied to crops. This is in accordance with theory. The amount of non-ammoniacal nitrogen in the dung depends on the quantity of litter supplied to the stock, and the ammoniacal

nitrogen, which is in a form liable to be lost, is held more or less mechanically by the cellular mass of the damp manure, so that the greater the bulk the greater the amount of ammonia retained. A minimum loss occurs in the manure heap under the following conditions:—

1. Anaerobic conditions should be induced as far as possible by keeping the heap moist and well compacted. This is best attained by keeping the animals in boxes or courts, allowing the dung to accumulate beneath them, and adding fresh litter daily so that the animals rest on a dry surface. Thus the air is excluded, the heap is moistened by liquid excrement, and the evaporation of ammonia is reduced to a minimum.

2. The heap should be roofed over so that it is protected from rain. If water is allowed to percolate through the manure it washes out the valuable soluble constituents and considerable loss is occasioned. In order to prevent soakage of the urine to the subsoil or the drains the bottom of the court should be made of impervious material.

3. Where an excessive amount of urine is produced, as is the case in dairy herds, special tanks should be constructed into which the liquid excrement may be led by a system of drains. The tanks may be emptied from time to time and their contents distributed over pastures or young corn crops. A thousand gallons of liquid manure is equivalent to 3 cwt. of kainit and 100 lb. of sulphate of ammonia.

The Application of Farmyard Manure.—The maximum value is obtained from dung when it is carted to the fields as soon as it is made, and ploughed in; but this is only practicable at certain seasons of the year. Under average conditions dung must necessarily be accumulated for a considerable time. It may be applied to the land after harvest, carted and spread during periods of hard weather during the winter, or placed in the drills for certain root crops in spring. Certain factors require consideration before a system of application can be evolved: (1) The greatest proportion of farmyard manure is accumulated during the

house-feeding period from October to April, and, if possible, the whole of this manure should be applied to the land before the last of the crops are sown in the spring, because the heat of summer is inclined to desiccate the heaps and cause very great loss. (2) As ploughing is generally completed in January that portion of dung accumulated from October to December only is available for spreading on the stubbles, and manure made from January to May has to be applied in ridges for the root crops. (3) The only manure available for application to the stubbles after harvest is that made and stored during the summer, provided, of course, that all the winter dung has been applied.

In practice most of the dung should be applied during winter and autumn when low temperature conditions reduce the activity of fermentation and the loss of nitrogen. Further economy is effected by spreading and ploughing it in as quickly as possible.

In the wet, cool climate of our northern and western districts as much dung as possible is applied to the stubbles in autumn and winter, advantage being taken of frosty weather to get the manure out to the fields. By applying the remainder of the material in ridges, the courts are completely emptied before turnips are seeded. But in dry southern and eastern localities it is found that the application of dung in the drills for root crops is liable to dry out the soil, and the manure made after New Year is often held over until the stubbles have been cleared in the autumn.

The liquid manure accumulated in tanks during the feeding period gives the best results when applied either to rotation grasses periodically throughout the growing season, or as a top dressing to cereal crops in the spring. If it is too strong, however, and especially if the soil be dry, it is inclined to "burn" the herbage and may have to be diluted. A preliminary trial should be given on a small scale, and if no ill effects follow the tanks may be emptied forthwith.

Other General and Organic Manures.

Guano.—The original guano, consisting of an accumulation of the droppings, feathers, and remains of sea birds, was obtained from a number of rainless islands off the coast of Peru. It contained about 12 per cent. nitrogen, 22 per cent. phosphate, and 3 per cent. potash, all of which were readily available as plant food. Many other guanos have since been imported, but they are nearly all poorer in nitrogen than the original substance.

Phosphatic guano has originated like ordinary guano, but in a rainy climate. It has been washed almost completely free of nitrogen, and some samples are practically pure calcium phosphate.

Equalised guano is a naturally occurring low grade guano made up to contain a given percentage of nitrogen by the addition of sulphate of ammonia.

Fish guano is not a true guano but is prepared from fish offal by extracting the valuable oil and grinding up the dried residue. Its composition varies, but an average analysis is 9 per cent. nitrogen, 15 per cent. phosphate, and 0·6 per cent. potash.

All the guanos are thoroughly reliable and useful manures, though they may be rather expensive in comparison with simple manurial salts. Many farmers, however, and particularly those on light land, maintain that slow acting organic manures of this kind have a better and more lasting action than quick acting soluble substances.

Shoddy.—This is a waste material—produced in the manufacture of woollens—which is very variable in quality and may contain anything from 3 to 13 per cent. of nitrogen. It is largely used as a constituent of compound manures. Although it is slow to decompose in the soil it is useful for most crops that have a long growing season.

Soot.—Soot contains normally about 4 per cent. of nitrogen in the form of sulphate of ammonia, but may contain considerably more. It is quick to act on the soil and is largely used as a spring dressing for wheat, about 25 bushels,

equivalent to 1¼ cwt. of sulphate of ammonia, being applied to the acre. Its dark colour improves the temperature of the soil, and it is useful in checking the activities of some insect pests. Its chief disadvantage is its dirtiness, and farmers are almost obliged to supply their labourers with special suits of clothes to wear when handling it.

Seaweed. — Seaweed has been used for generations along the coastal districts of Great Britain and Ireland for improving the fertility of the land. Different species of weed have different values, but a ton of average mixed material contains 9 lb. of nitrogen, 25 lb. of potash, and 2 lb. of phosphoric acid—equivalent to 4·4 lb. phosphate. It is therefore as valuable as dung but richer in potash and poorer in phosphates. In certain parts the seaweed is specially cut and harvested, but along most rocky coasts it is carried ashore by undercurrents during stormy weather in autumn and winter. Seaweed is particularly useful for potatoes, and is largely used in the early potato districts of Ayrshire, Cornwall, ard the Channel Islands. It may be applied at the rate of 20 to 30 tons per acre.

Rape Cake.—This is the residue obtained when the oil is extracted from rape seed. It is not very useful for feeding to stock and is used in this country as manure. It contains 5 per cent. of nitrogen, 4 per cent. phosphate, and 1 per cent. of potash. It decomposes fairly slowly, and as it increases the humus content and improves the texture of the soil, it forms a useful substitute for farmyard manure.

Compound Manures.—Every manure merchant prepares mixtures to suit different crops. These fertilisers are compounded to suit average conditions, and must necessarily be more or less unsuitable for any particular type of land, and they are usually considerably more expensive than equivalent mixtures of simple manurial salts. Farmers are therefore recommended to buy simple manures and apply special mixtures to suit their own conditions.

Green Manuring.—Green manuring consists of cultivating a crop and ploughing it in for its manurial value. As a rule only catch crops—*e.g.* white mustard, trefoil, and Italian

rye-grass—are grown for this purpose, and the system is seldom practised except where it is necessary to improve the water-holding power of a light hungry soil, or where, on rich land, there is a risk of loss of nitrates between the separation of one crop and the sowing of the next.

The Purchase of Manures.

On account of the large number of manures available, and their varying compositions, it is necessary to have a system by which different fertilisers can be compared on a basis of costs and value. This comparison is made on the cost of 1 unit, which is 1 per cent. of a ton, and is obtained by dividing the price of a ton by the percentage of the active manurial ingredient.

For example, 30 per cent. superphosphate costs £3 per ton.

$$\frac{£3}{30} = 2s. = \text{cost per unit of soluble phosphate.}$$

Again, 60 per cent. mineral phosphate costs £3 per ton.

$$\frac{£3}{60} = 1s. = \text{cost per unit of insoluble phosphate.}$$

The present cost of soluble phosphate is 1s. more than insoluble phosphate; therefore in all cases where a quick-acting manure is not required the ground mineral phosphate should be purchased.

In the case of mixed fertilisers, however, which contain two or more manurial ingredients, the comparison and valuation is somewhat different. With regard to the unit values it is customary to assume that the value of the nitrogen and potash is the same as in the nitrogenous and potassic manures, the soluble phosphates the same as in superphosphate, and the insoluble phosphates the same as in slag or mineral phosphate.

At the date of writing the unit value of nitrogen is 10s., that of insoluble phosphate 1s., and that of potash 3s. What

is a mixed manure containing 9 per cent. nitrogen, 15 per cent. phosphate, and 6 per cent. potash worth per ton?

9 units of nitrogen at 10s. . . .	£4	10	0
15 „ phosphates at 1s. . . .	0	15	0
6 „ potash at 3s. . . .	0	18	0
Value per ton . .	£6	3	0

Therefore if the market price of the manure is much more than £6, 3s. plus the cost of mixing it is too dear.

Unit values cannot be taken absolutely literally, however, and must be used for guidance only, as many manures which have a physical action on the soil, or are particularly suitable for certain purposes, have a value that cannot be assessed by comparison with the chemical fertilisers.

Mixing Manures.—When manures are mixed together for convenience of application the following precautions should be taken:—

1. Manures containing quicklime should not be mixed with dung, guano, or ammonium salts, otherwise ammonia will be lost.

2. Nitrate of soda should not be mixed with an acid manure—*e.g.* superphosphate—as there is a risk of nitric acid being displaced.

3. Dissolved phosphates such as superphosphate should not be mixed with manures containing lime or calcium carbonate, which would cause the soluble phosphate to revert to an insoluble form.

For thorough mixing, the manures, in the proper proportions, should be put down layer upon layer on a suitable floor. The flat-topped heap made in this way should then be shovelled over by starting at one end and cutting vertically downwards through the different ingredients. This turning may be repeated until the material is sufficiently well mixed, and it is also well worth while to pass the mixture through a riddle in order to remove lumps, which are then easily broken down. A good riddle for this kind of work is the type of screen employed by plasterers for riddling sand and gravel. This screen is propped up at an angle and

the material is thrown against it so that the small particles pass through and the lumps roll back to the feet of the operator.

A number of firms make machines for mixing manures, but the cost of such a mixer can only be justified on a very large farm. Practically all manure merchants employ mechanical mixers and they are usually prepared to mix fertilisers for a few shillings per ton.

The best compound fertilisers are generally made up of sulphate of ammonia, superphosphate and one or other of the potash manures, together with a small amount of a "drier" such as steamed bone flour. Even carefully selected materials of this sort tend to "cake" slightly after they are mixed, thereby causing some difficulty when the manure is being sown. This trouble can be overcome if the fertiliser is mixed and sown on the same day, or, if this is not convenient, the manure can be riddled once more after the "caking" is completed, when it will be found that it will retain its fine free texture.

Lime.

The practice of adding lime to the soil is very ancient, and for hundreds of years lime and dung were the only fertilisers applied to the land. Chemical methods have been devised for measuring the "lime requirements" of soils, and although such estimations are valuable they cannot be used as an absolute guide. They must be taken in conjunction with evidence afforded by the herbage that the soil is producing. A shortage of lime is indicated by the accumulation and slow decay of organic matter, often forming thick springy turves of unrotted plant debris, by the presence of certain weeds such as sorrel, spurry, and yellow corn marigold, and by the failure of crops like red clover and barley.

Although lime is a plant food, its chief use is not to supply the crops with calcium, but to act upon the soil itself. Its effects upon the crops are therefore chiefly secondary. It improves the texture of the soil by flocculating the clay

particles and is particularly beneficial to heavy land. It acts as a base by neutralising humic and other acids produced during the decomposition of organic matter, and it is required by the nitrifying bacteria if they are to carry on their beneficial action in the liberation of plant foodstuffs. It is required in the soil when manures like sulphate of ammonia and superphosphate are used; and it is beneficial in preventing the accumulation of certain slime fungi which are injurious to crops, such as the fungus producing finger-and-toe disease in turnips.

Since lime is continually going into solution as calcium bicarbonate, and being washed to the drains, it has to be replaced periodically in all ordinary soils.

Lime Shells.—Lime shells are prepared by burning limestone rock with coal at a temperature which reduces the calcium carbonate to calcium oxide or quicklime with the liberation of carbonic acid gas. Their exact composition depends on the purity of the rock, which may be anything up to 90 per cent. pure calcium carbonate. Quicklime is hygroscopic and also takes up carbonic acid from the air. Thus, unless the quicklime is freshly prepared it is liable to contain a portion of hydroxide and carbonate.

It is usual to apply lime shells at the rate of about 2 tons to the acre. Smaller quantities are difficult to distribute evenly. The usual method of application is to cart the lime out to the fields after the autumn ploughing has been completed and to deposit it in small heaps at regular intervals. Rain and contact with the atmosphere soon cause the heaps to swell and crumble, and the lime is "slaked" or changed to calcium hydroxide. When the lumps are completely pulverised the lime is scattered over the ground with shovels, and that portion which is not washed into the soil by the winter rains is worked into the ground by the spring cultivations. The lime is at first caustic in effect and should not be applied to grassland and growing crops, but in the form of hydroxide it is washed into the soil and well distributed, and though it finally reverts to the form of carbonate by absorbing carbonic acid, it is in such a

fine state of division that it is usually more immediate in action than is ordinary ground limestone. Sometimes, however, it is desirable to apply this form of lime to grassland. In such cases it becomes necessary to slake the quicklime thoroughly if "scorching" the grass is to be avoided. Slaking is best effected by carting the lime into a large heap some considerable time before it is to be applied, covering the heap with earth, and allowing it to slake slowly by absorbing moisture from the air; but in dry periods the action may be hurried on by the application of water.

Many limestones which are burned for agricultural purposes contain more than 50 per cent. of magnesium carbonate. Under most conditions magnesian lime produces good results, but an excess of magnesia in light soils is considered to be harmful.

Ground Lime.—This is prepared by grinding lime shells to a fine powder between steel rollers. Its action is similar to that of lump lime, but its fine state of division renders it easy of distribution by an ordinary manure-spreading machine, and small quantities produce as much temporary improvement as large dressings of unground material. Some farmers apply ground lime once every four to six years in dressings of 10 cwt. per acre.

Ground Limestone.—This is prepared by grinding the naturally occurring rock to a fine powder. It may be slow to act if it is not finely ground and uniformly distributed throughout the soil. In time, however, it dissolves as bicarbonate, and it is advantageous in that it has no caustic action and can be safely applied for the improvement of grassland. Since $1\frac{3}{4}$ tons ground limestone are equivalent in effect to 1 ton of lump lime, it is more costly than the latter to cart and spread.

Chalk.—Chalk, where it occurs naturally and can be obtained cheaply, may be applied to the soil instead of lime. It is difficult to grind and is usually applied in heavy dressings of about 20 tons per acre at long intervals.

Gas Lime.—Lime is used in the purification of coal-gas

for the absorption of volatile sulphur compounds, and when its power is exhausted it is marketed as gas lime. Fresh gas lime is a greenish, evil-smelling substance containing unoxidised sulphur compounds which are poisonous to both plants and animals, and may be used as an insecticide on badly infested land. It may be used for the improvement of the soil like other forms of lime; but as it is very poisonous it should be mixed up with soil and left in an exposed heap for about a year before it is applied to the stubbles. During the storage the lime becomes oxidised to a harmless mixture of calcium sulphate, calcium carbonate, and free lime.

Waste Limes.—Waste limes, usually in the form of finely divided and rather wet calcium carbonate, are sometimes obtainable from sugar factories, paper mills, etc. They may be used for agricultural purposes in place of ground limestone, but they are often so wet and pasty that they are difficult to spread. Chemically precipitated calcium carbonate is relatively quick acting owing to its fine state of division.

Gypsum.—Gypsum or calcium sulphate is capable of maintaining the lime reserves in the soil, and since the earliest times its application has been known to improve certain crops. It is seemingly capable of liberating a certain amount of potash from clay, is very beneficial to clover, and probably supplies certain cruciferous crops with sulphur. Superphosphate of course contains a large proportion of gypsum.

CHAPTER V

IMPLEMENTS AND CULTIVATIONS

The Plough and Ploughing.

THE first object of ploughing is to prepare a tilth or fine soil condition suitable for the germination of seeds. Ploughing alone may be insufficient to attain this end, but in almost every case it is the first and principal operation. Ploughing is also practised for the burial of surface vegetation, weeds, stubble, growing crops, and manures. It modifies the texture of the soil in such a way as to regulate the retention of water; it mixes and redistributes the soil particles; it promotes weathering and activates the micro-organisms.

Operations for the control of soil moisture are of the utmost importance. Most clays, because of their close, water-retaining texture, tend to be too damp in winter, and they must be cultivated in such a way that drainage is encouraged and the surface dried sufficiently early in spring to permit of timely seeding. In sandy soils, on the other hand, drainage is as a rule so rapid that the crop may be stunted from lack of water. Sands must therefore be kept well compacted to decrease the size of their interspaces and to encourage the rise of capillary moisture; but the capillary passages must be interrupted before they reach the surface to prevent the water from rising too far and being lost by evaporation. Light soils may be consolidated by exposure to the weather after ploughing and by rolling; then a loose surface mulch should be prepared by shallow cultivating and harrowing. In all soils a loose open condition at the bottom of the furrows, which is accentuated by the ploughing in of green herbage or long dung, will prevent the desirable rise of water from the subsoil; but in time consolidation is

effected by the beating action of rain, which brings about a more thorough compaction than any form of tillage. Obviously ploughing immediately before seeding may be undesirable, and in practice most crops do best on a "stale" furrow.

The most common English style of ploughing is to invert the soil so that the furrow-slice remains unbroken, whereby the field is laid out in crested furrow-slices. This fashion was established before the advent of the seed drill, and it leaves the land in a suitable state for the distribution of seed by hand. It is also useful in that it leaves the furrows well exposed to the action of the weather and promotes drainage. About 1885, however, digging ploughs were introduced. These implements turn the furrows over in a completely broken condition, leave the land almost level, and in some cases in a satisfactory condition for drilling.

The depth of ploughing depends to such an extent on the nature of the soil that no hard-and-fast rules can be laid down in regard to it, and every farmer must determine the most suitable depth for his own land. Deep cultivation creates a deeper root bed for the crop, and, by bringing a greater volume of soil under the influences of weathering and aeration, tends to increase fertility; but more often than not the soil is not sufficiently deep to make deep ploughing profitable, for it is useless to waste energy in working a medium that is incapable of producing any return. Further, the bottom layers may even contain injurious substances which when brought to the surface have a deleterious influence on plant growth. In practice the depth is limited, as no matter how deep and fertile a soil may be, a point is reached where the draft becomes excessive and ordinary implements cannot overcome the resistance. Again the lower horizons of many soils are stony and ploughs are incapable of working them. No matter what the most suitable depth of ploughing may be, it is advisable to vary it slightly from year to year in order to prevent the consolidation of any particular stratum. The treading of the horses and the pressure of the slade for example may occur to such an extent as to form a pan.

Sometimes an especially deep ploughing is given to rid the land of weeds and their seeds, and the subsequent ploughings are adjusted to prevent any of the material from being returned to the surface.

The width of the furrow-slice is limited by the available power, and is determined by the kind of work that is required. For example, if a farmer is ploughing to prepare a bed for the broadcasting of wheat, which has been found to do best in rows 7 in. apart, it is obviously undesirable for him to plough more than 7 in. at a time. A practical limit is also reached as no ordinary plough can invert a furrow more than 12 to 14 in. broad—it simply raises the soil and allows it to fall back in the furrow—but the deeper the work the greater the breadth possible. The broadest furrows are usually turned when cross ploughing in the spring, as the land is easily worked and it is essential to hurry forward with the preparation of the seed-bed.

Ploughs are constructed to work the land to a given depth and turn over a given breadth of furrow. Any plough cannot be expected to do any kind of work, though it may be adjusted for different purposes within certain limits. Farmers must therefore purchase implements to suit their own particular requirements, ploughs being obtainable for dealing with any type of land.

The method of ploughing has to be varied for different types of soil, different kinds of cropping, different times of the year, and for the prevalence or otherwise of weeds and rubbish. Immediately after harvest, it is the custom of many farmers who aim at the eradication of weeds to skim over the stubbles with ploughs fitted with broad paring shares; thus the weeds are cut off an inch or two below the surface and are soon desiccated and killed. At the same time any seeds that have been shed are partly buried, induced to germinate, and afterwards killed by the ordinary autumn or winter ploughing. If the land is moderately clean, cultivation may be substituted for skimming, and if weeds are practically absent it may be left until deep ploughing takes place.

As a rule heavy land is ploughed early so that it may be

exposed to the flocculating action of winter frosts and subsequently easily worked into a "mould" in the spring. Autumn ploughing up and down the slope of a field that tends to be wet promotes drainage and induces warmth and earliness at seedtime. On no account should clays be ploughed when they are wet, for they will dry into brick-like masses that cannot be broken down; nor should they be worked too fine in autumn in preparation for a winter cereal, for the surface may run into a sticky plastic mass which hardens to a pan and is difficult to break up in spring. On light and sandy land the main object of ploughing is to destroy weeds, and the operation may be performed at any time, provided that the plants are not allowed to seed. Consequently much of our light land is ploughed for the first time in the preparation of the spring seed-bed; it is even advisable to leave the land consolidated until this time, as the free drainage promoted by stirring tends to increase the loss of valuable nitrates. Spring ploughings are mostly performed in preparation for sowing; they are frequently conducted in a cross direction to facilitate the breaking up of the autumn furrows, and they are usually shallow so that the fine mould produced by the winter frosts is not worked down beyond the depth of seed planting. Many farmers of medium class land use ordinary ploughs for autumn work so that the land benefits by the weather, and chilled digging ploughs for spring stirring, because these implements are superior in the production of a fine tilth and quicker in getting over the ground.

The Practice of Ploughing.—When the ploughing of a field is commenced the first operation is the marking off of the headland (which may be 5 to 6 yards wide) by turning over a furrow-slice parallel to the boundaries. The headland may be marked off round either the whole field or three sides only, though in a rectangular field two headlands may suffice. The next operation is to mark off the field into "lands" by setting out ridges parallel to one side, preferably the longest. Lands are necessary in all cases where an ordinary plough is used, in order to economise time in turning at the furrow

ends, but they are also useful in acting as guides for the broadcasting of seed, and in facilitating surface drainage. The size of a "land" in ordinary arable practice is 22 to 24 yards, but on heavy land which tends to be water-logged they may be made as small as 5 or 6 yards in order to introduce a large number of open furrows which serve as shallow drains.

The usual form of ridge is simply made by turning one furrow-slice against another, and a strip of unturned land remains under the crest. However, it may be desirable to invert the whole of the sod, and this is done by making a split-ridge setting. To do this, two shallow furrow-slices are turned outwards, leaving a bare strip of soil where the ridge is to be set out; the plough is then set to go to the normal depth, and the double furrow-slices are turned against each other in the ordinary way. The methods of setting ridges vary greatly; they depend on the locality, on whether the field is lea or stubble, and on whether ordinary or competition work is required.

Where the ridges have been set out 22 yards apart, the method of working is to plough round and round the first ridge in a clock-wise direction until a strip of 11 yards wide has been turned over: this process is called "gathering." The ploughman then proceeds to the second ridge and again gathers 5½ yards of land on each side. Henceforth it saves time to return to the unturned land between the two gatherings and plough it outwards in the direction of the two ridges by moving in an anti-clockwise direction until the whole of the soil is turned over. This part of the work is called "splitting" or "casting" (see Fig. 2).

When the last slice is turned over an open furrow two horse-walks wide is left between the ridges. It is usual to leave the land in this condition; but where greater drainage is required a "mould-furrow" finish may be given, which consists in turning one more furrow out of the subsoil. Sometimes the last two furrow-slices are ploughed back to give a "furrow-back" finish and fill the horse track with soil. In all cases the last furrows must be ploughed back

before the commencement of the working of the land as a seed-bed.

When the land is ploughed again, the furrow-slices are turned in the opposite direction so that the open furrows are converted into ridges, and the ridges into open furrows; thus the surface of the field is kept practically level. On certain heavy, wet soils where narrow, high lands are desirable, it is customary to ridge up five times and plough back four times in every nine ploughings: this practically balances the

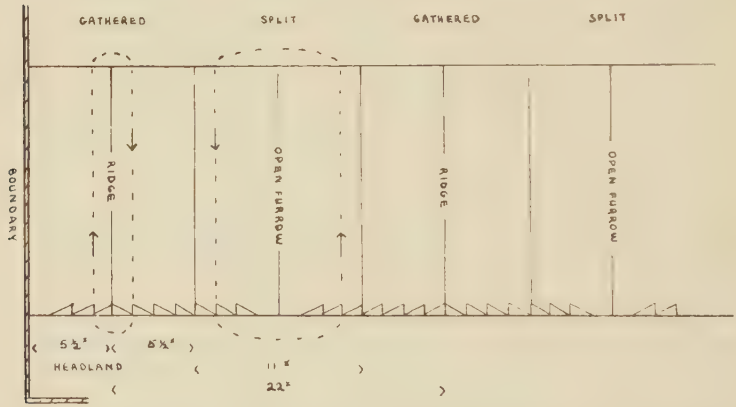


FIG. 2.—Diagram showing Method of Ploughing. The arrows and dotted lines indicate the travel of the plough in turning the first gathering and splitting furrows.

washing action of rain, which in time tends to level down the crests and fill the depressions.

The headland may be gathered at one ploughing and split at the following, or where it runs right round the field it may be ploughed round and round, turning it in one season and out the next.

The size and shape of the furrow-slice are determined by the hitch of the plough, the adjustment of the wheels, and the setting of the share and coulter. It is essential that the plough should be adjusted to remove all side drag or excessive pressure on the land slide or wheels, otherwise the draft is greatly increased and the horses are overworked. It

is obvious that the breadth and depth of the furrow can be varied by moving the furrow and land wheels respectively. If the plough tends to drag either towards or away from the land, the hitch on the quadrant head should be moved until true alignment is attained, and if the plough is inclined to work out of the soil or go too deep, the hitch on the hake should be moved up or down until the implement moves evenly and in perfect balance.

When the plough is properly adjusted there is a slight "set" on the coulter and share towards the left to make it hold the land, and the point of the share extends slightly downwards to hold it in the ground. When the plough has a tendency to work out of the soil (although the hitch is in a position that has previously resulted in good work) it shows that the point of the share is worn, and sharpening is necessary to rectify the trouble. If the ground is so hard that the plough cannot be got to travel at its proper depth an improvement may be effected by fitting a projecting bar-pointed share and lengthening the draft chain. If the furrow bottom is uneven and gouged out in places the plough is running on its point; this is due to the point being bent too much downwards and is remedied by fitting a share with a more gradual taper. When the plough bears down heavily on the furrow wheel it shows that there is too much dip on the wing of the share, and the cutting edge of the wing should be raised. On the other hand if the pressure is too great on the land wheel the wing of the share is bent too much upwards and should be lowered.

No plough will produce satisfactory results unless its rubbing surfaces are scouring properly, that is the metal must take on such a high polish that the adherence of soil is absolutely prevented. Ploughs that are in good condition should have their shares and mould boards coated with oil before they are set aside; this prevents rusting, and good work is possible immediately the implement is returned to use. When a plough fails to scour and soil collects in the concavity of its mould board,

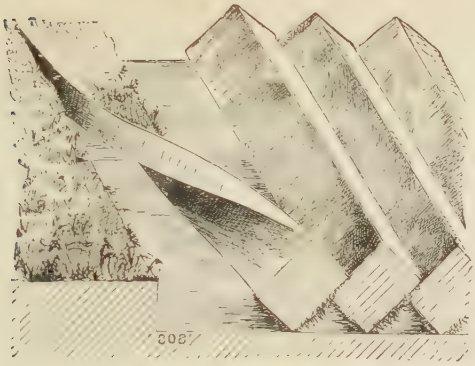
it is evident either that the metal is unsuitable or that the breast is of the wrong shape (see The Plough, p. 81).

When the object of ploughing is to bury herbage a skim coulter should always be fitted. The skimmer pares off that portion of the vegetation which grows on the shoulder of the furrow, where, because of exposure to air and light, the vegetation is liable to continue its growth if an ordinary coulter is used. Where crops are being ploughed in, or long manure is being buried, a drag chain and weight should be employed to pull the material beneath the furrow and effectively put it out of sight.

Different styles of ploughing are illustrated in Fig. 3. No. 1 is the ordinary style of ploughing performed by an English implement: the breadth of the furrow is greater than its depth, and the furrow is inverted without being broken. No. 2 is a style adopted for lea work, and in the preparation of land for the broadcasting of seed: the furrows are well set up and a large surface is exposed to the action of weathering. No. 3 is the work of a plough with a digging breast, which pulverises the furrow as it turns it over: it is the common style of spring cross-ploughing for the production of tilth, and is the kind of work performed by most American ploughs.

The following are the requirements in good ploughing: (1) Each furrow must be straight from end to end. (2) The top lines of the furrow-slices should be absolutely uniform without breaks and depressions, and the furrow-slices should be of uniform thickness. (3) All vegetation, manure, etc., should be properly buried. (4) There should be no unturned ground. (5) Where the land is ploughed to receive broadcast seed, the furrows should be trapezoidal and well set up, there should be no gaps through which seed might fall too deep, and the land should be left as firm as possible. (6) Where digging ploughs are used the soil should be completely broken up, not only on the surface but to full plough depth, and there should be no large air spaces which might interfere with the rise of water.

(1)



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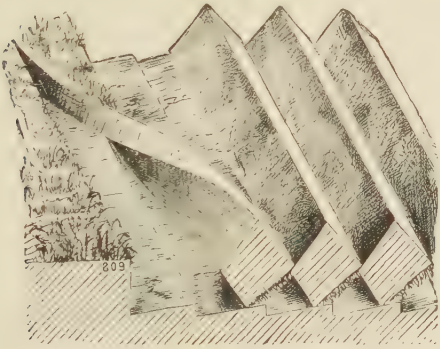

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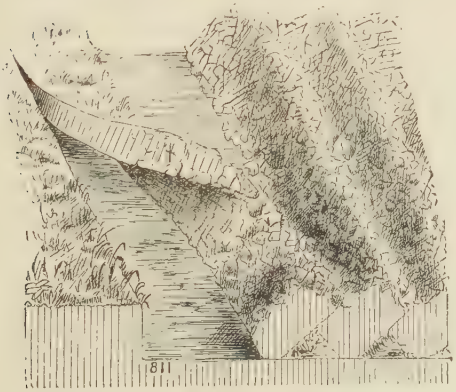


FIG. 3.—Styles of Ploughing.
(1) Rectangular Furrow, Unbroken. (2) High-cut Crested Furrow, Unbroken.
(3) Rectangular Furrow, Broken.

Ploughs and their Construction.

The earliest form of plough was simply an enlarged hoe which stirred the soil as it was dragged along, and it was not until the eighteenth century that ploughs approaching the modern type were invented.

The Wheeled Plough.—The parts of the wheeled plough, which is the implement in common use at the present time, are illustrated in Fig. 4. For the position of the slade and side cap, however, the illustration of the digging plough should be examined.

The nature of the work performed by the plough depends on (1) the construction of the share, which gives the horizontal cut, (2) the coulter, which gives the vertical cut, and (3) the mould board which is curved so that it inverts the furrow.

The draft of the plough is brought about by the resistance of the earth to the two cutting edges, the energy required to raise the soil and invert it, and lastly, the friction of the plough parts against the soil surfaces. This friction is of very great importance and most of the draft is absorbed in overcoming its resistance. If the plough is properly hitched there will be little or no friction against the side cap, the pressure on the slade will largely depend on the weight of soil resting on the mould board, and most of the friction will be due to the size and length of the breast. In all cases friction is greatly reduced when the plough surfaces are highly polished.

The Mould Board or Breast.—The mould board may be made of cast-iron, but in most modern ploughs it is constructed of soft centred or soft backed steel. A steel breast has a wearing surface of high-carbon metal which is extremely hard and takes on such a high polish that the draft is minimised. High-carbon steel alone, however, is too brittle to be satisfactory, and has to be backed with low carbon metal which is tough and strong and prevents fracture. For average conditions and for soils which are more or less free from sharp cutting grit, steel mould boards scour better than other types, but they do not wear as

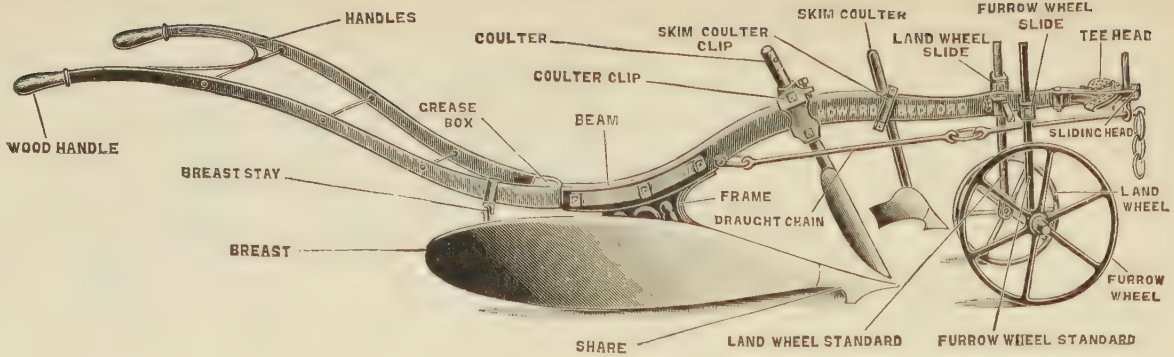


FIG. 4.—Ordinary Wheeled Plough. (*Howard.*)

FIG. 5.—Extreme type of English plough with especially long mould board designed for fine work, ploughing competitions, etc. Note drag-weight and chain. (*Hornsby.*)

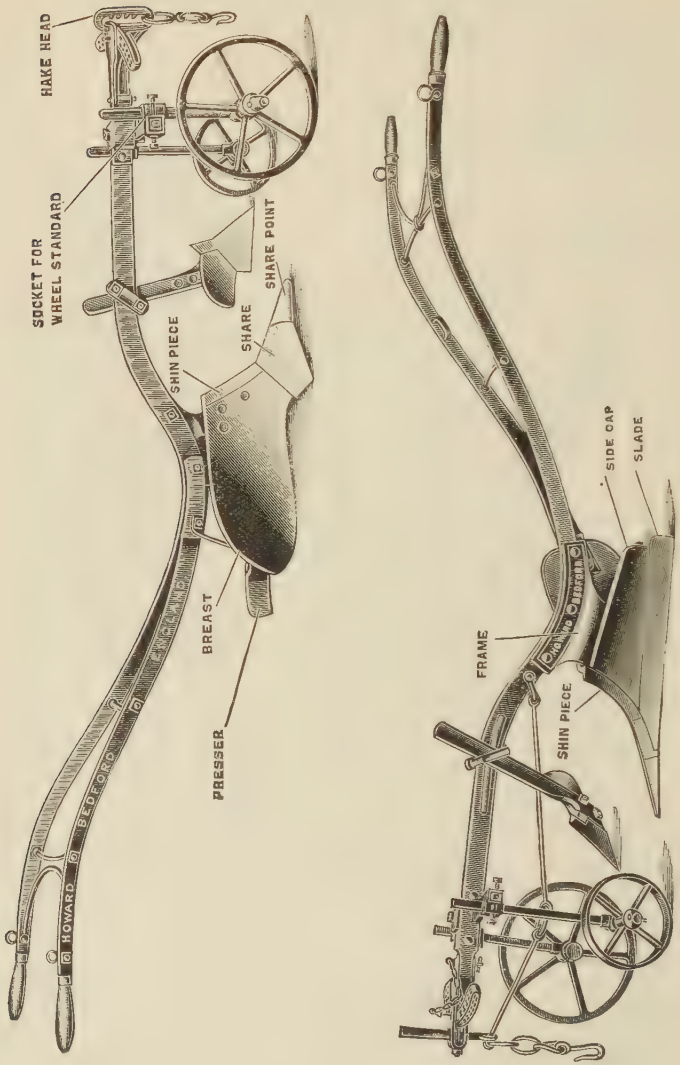


FIG. 6.—Chilled Breast Digging Plough. (*Howard.*)

well as chilled cast-iron, and for work in sharp gritty soils they are inferior to the chilled metal breasts used on digging ploughs.

The mould board is curved to invert the furrow, and the curvature and length of the mould board are concerned with the pulverisation of the soil. When the breast is long and the screw gradual the soil is turned over without the furrow being broken and the slice is pressed firmly against the previous slice; but, owing to the large surfaces and the amount of inert soil resting on the mould board, the draft of such a plough is exceptionally heavy (see Fig. 5).

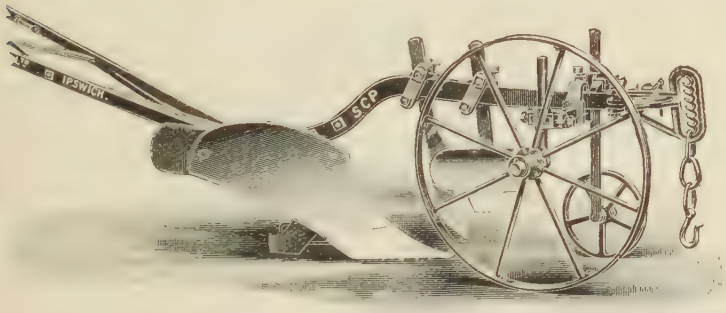


FIG. 7.—Deep digging plough to work soil to a depth of 14 in. Note the short breast to reduce friction and the very large furrow wheel to allow of deep setting. (*Ransomes.*)

On light soils short bluff mould boards are used which dig up the soil and turn it over rapidly (see Fig. 6). Not only is the surface of the mould board greatly reduced on this type of plough, but the side cap and slade are made correspondingly smaller, the draft being consequently exceptionally light. The reason that a short mould board cannot be used for the working of heavy land is that tenacious clay cannot be made to follow the sharp curvature of the breast, and consequently the plough will not scour properly and cannot do good work. It follows that for all intermediate types of land the shortest mould board that will scour properly should be selected in order to reduce the draft.

Fig. 7 illustrates a trenching or deep digging plough.

The mould board of this implement is exceptionally deep to enable it to invert a very large furrow, and it is made as short as possible to reduce the draft. The plough would be suitable for medium and light land only.

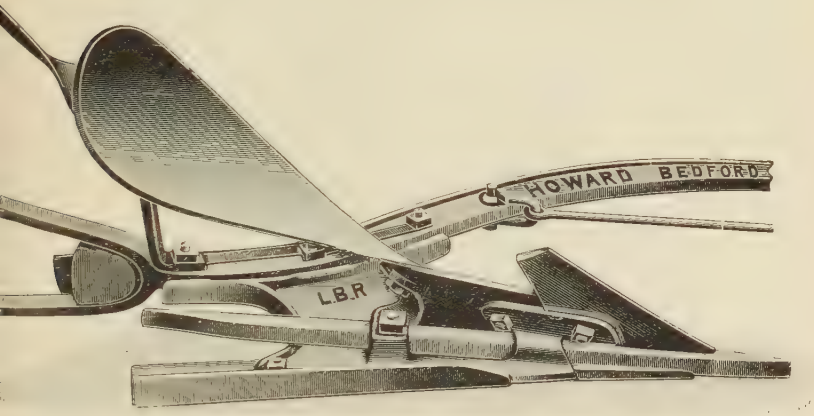
The Share.—Most modern shares are made of cast steel which wears well in average soil; but older types of ploughs were almost always fitted with shares of wrought-iron—a material that is still employed in districts where swing ploughs are in common use. The outstanding advantage of wrought-iron is the ease with which it can be welded, and ordinary blacksmiths can restore a worn share to its proper shape in a few minutes by hammering on another piece of metal. Shares wear most rapidly in stony land, and consequently many farmers working this type of soil prefer wrought-iron shares because they can be sharpened cheaply. When steel shares become worn they may be sharpened by heating, hammering the metal out to the desired shape, and re-tempering; but this can only be performed once or twice, after which replacement becomes necessary. Shares are obtainable which have the bottom layer of metal hardened. When they are in use the cutting edges are maintained by the more rapid wear of the softer upper portions, and sharpening is unnecessary.

Chilled iron shares, as used on many digging ploughs, can neither be welded nor hammered into shape; if sharpening is necessary it has to be done on a grindstone, and when wear has gone too far renewal of the part becomes necessary.

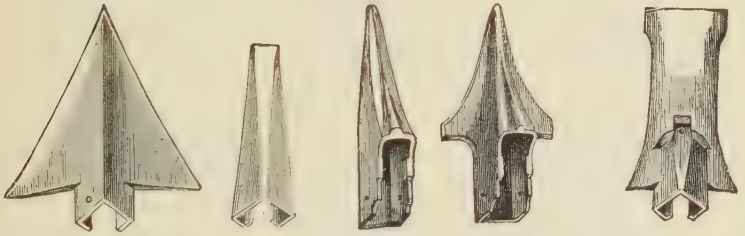
Bar-point shares have been devised for land that is very hard and stony, and where ordinary shares wear out rapidly; they cannot be fitted to ordinary plough bodies, but special bodies for their attachment are obtainable. The principle of the device is to replace the advanced cutting edge of the share with the chisel-pointed end of a long solid bar, which can be advanced, turned or reversed in a few seconds to make good the wear. The very advanced point that is possible is particularly useful for land which is hard of penetration.

A number of types of shares are illustrated in Figs. 8 and 8*a*.

The Coulter.—The coulter, like the share, may be made of steel or wrought-iron, and has to be sharpened or renewed



Reversible and Adjustable Bar-point Share.

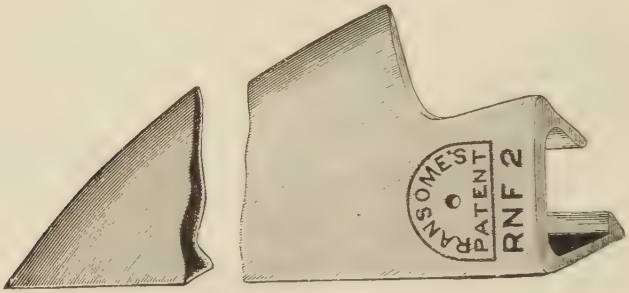


Ridging Shares. Subsoil Shares. Potato Share.

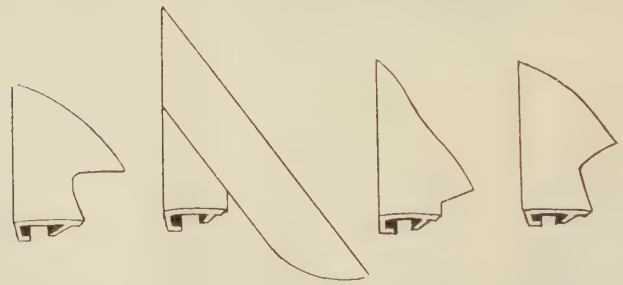
FIG. 8.—Plough Shares. (*Howard.*)

when it becomes inefficient through wear. It is secured to the beam of the plough by means of a clamp, and has a certain backward and forward range of adjustment. The coulter stem may be made round so that the blade can be given a "set" towards the land if necessary, or the same object may be secured when the stem is flat by the

use of iron wedges. For ordinary work the point of the coulter is set forward so that it forms an angle of about 55° with the slade, and it approaches very near to the point of the share; but the coulter is advanced considerably when an absolutely unbroken furrow-slice is required. When the



Self-sharpening Chilled Share.

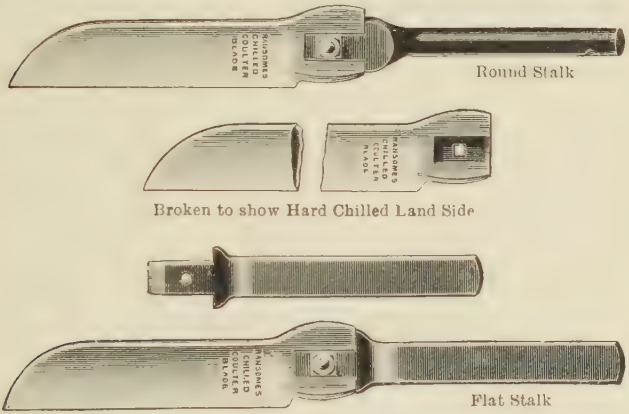


Square work. Paring. Stony land. Crested work.

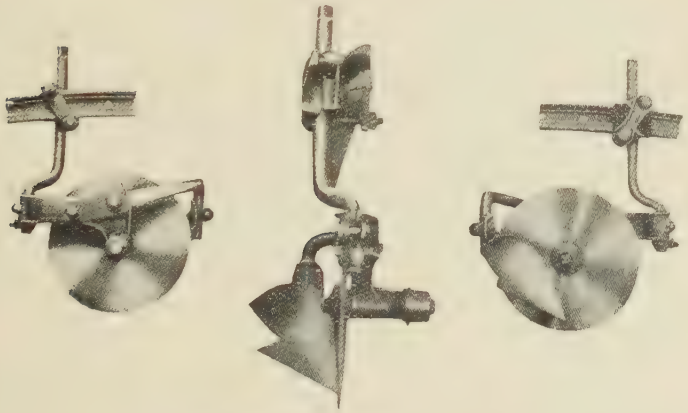
Fig. 8*a*.—Plough Shares.

land is stony, and fragments tend to jam between the coulter and the share, thereby upsetting the balance of the plough, a rolling disc coulter should be used. This form has a rotary motion, rides over obstructions, is self-sharpening, and decreases the draft on the horses; when renewal is necessary new discs are obtainable to fit on the existing sockets. Skim coulters should always be used when herbage and dung have to be ploughed in, as they remove and bury that portion of the vegetation which is liable to protrude

between the furrows. A modern knife coulter and a combined rolling coulter and skimmer are illustrated in Fig. 9.



Self-sharpening Chilled Coulter. (*Ransomes.*)



Rolling Coulter and Skimmer. (*Oliver.*)

FIG. 9.—Coulters. (Compare with wrought-iron and skim coulters, Fig. 4.)

The Digging Plough.—The digging plough (Fig. 6) is a type that has been evolved in America, where suitable models are made for every kind of soil. In this country, however, few digging ploughs are used except for working

light land and cross ploughing medium land that has been exposed to the action of frost throughout the winter. The action of a digging plough differs from the work of a common plough in that the furrow is not pressed against the previous furrow, but the soil is caused to rise up the face of the mould board and fall over in a completely broken and pulverised condition, with the result that the soil is worked into a mould in addition to being inverted. Work of this type is not ideal in wet districts, and consequently diggers are by no means generally used, though they have an undoubted advantage in their speed and the quality of their work where the soil and climate are suitable. Although the pulverising action absorbs a good deal of energy not ordinarily required, the plough surfaces are so reduced, with consequent reduction of friction, that the draft of a digger is usually about two-thirds that of a common plough. The terms "digging plough" and "chilled plough" are frequently taken to be synonymous, but they are not necessarily so, the association having been produced by the fact that chilled breasts are usually best for light, sharp soil—the type of land on which the digging plough has established itself. Steel breasts are frequently employed and are superior on the heavier classes of land.

The handles of a digging plough are frequently short, and both the handles and the beam may be constructed of wood for the sake of lightness. An ordinary knife coulter is never employed, its work being performed by a shin piece, or cutting edge, fitted in front of the breast.

The Swing Plough.—This plough is generally used on the boulder clay districts of the North of England and throughout Scotland. It differs from the ordinary plough in having no wheels, very long handles, and a shorter mould board which produces more of a digging action. The absence of wheels makes the plough difficult to balance in uneven or stony soil, and the handles are therefore made very long to give the ploughman a good leverage. It is obvious that it is to the interest of the workman to have the plough properly set, otherwise he will have to apply his own strength

as a corrective, and no doubt the horses are benefited by not having to pull an implement which is out of balance and is throwing heavy pressure upon its wheels. Apart from this, however, there is less draft than with a common plough.

One-way Ploughs.—A one-way balance plough is illustrated in Fig. 10. Ploughs of this type are constructed

FIG. 10.—Balance "One-way" Plough. (*Ransomes.*)

with the object of enabling the plough to work backwards and forwards turning all the furrow-slices in one direction. The work of setting out lands is thus avoided, and the land is left without any open furrows. Another type of one-way plough is the turn-wrest implement, which is provided with double mould boards, shares, and coulters, but one body and one pair of handles; the compound parts are balanced and are swung from one side to the other when the plough is turned at the headland.

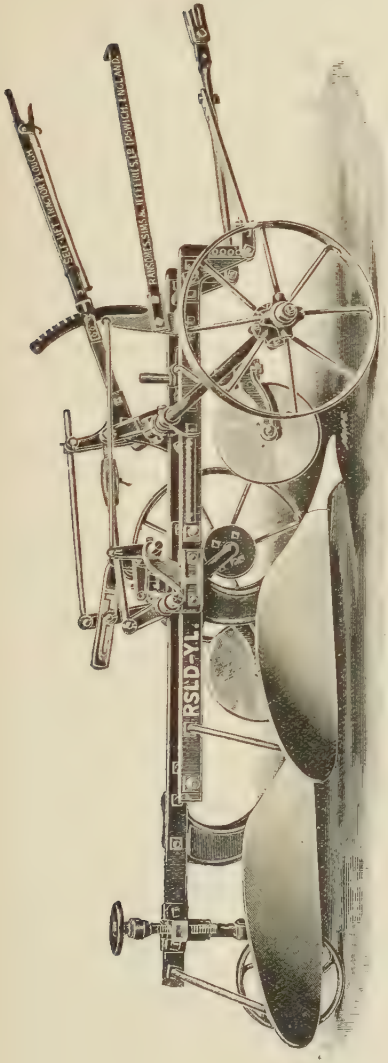
Multiple Ploughs.—Double furrow gang ploughs can frequently be profitably employed by light-land farmers, because three horses at most are required for their draft, and one driver only is necessary.

The multiple ploughs in most common use are tractor ploughs, which take two or more furrows according to the nature of the soil and the power of the engine. The plough bodies are bolted to an iron framework mounted on three wheels (Fig. 11). The hitch to the tractor is adjustable so that perfect alignment can be obtained, and all the control levers are long and set so that they can be reached from the tractor seat. The most ingenious part of the plough is the self-lift mechanism, which by the pull of a cord causes the plough to rise out of the ground when the headland is reached, and by a second pull drops it so that it re-enters the land when the turn is completed.

The Subsoil Plough.—Subsoiling consists of stirring up the soil to a greater depth than is reached by ordinary ploughing. It differs from trenching in that it does not bring the subsoil to the surface but leaves it broken and aerated *in situ*. Subsoiling is absolutely necessary where a plough-pan has been formed or where an iron-pan has been developed by a precipitation of iron salts a few inches below the surface. Even on ordinary soils it may be advisable to practise subsoiling in preparation for tap-rooted crops like sugar beet, carrots, and parsnips.

A subsoil plough is very similar to an ordinary plough without breast, share, or coulter, but with one large digging tine fixed below the body. In practice the subsoiler follows an ordinary plough and tears up the horse-walk, whereby the deep layers are aerated, drainage is facilitated and fertility is increased.

Ridging and Potato Ploughs.—A convertible ridging and potato plough is represented in Fig. 11. It can be seen from the illustration that the bodies, which are bolted to the beam, are removable and interchangeable. Ridging ploughs are of the double mould board type, and are used in conjunction with a marker to form ridges for root crops,



Self-lift Two-furrow Tractor Plough. (*Ransomes.*)

Convertible Ridging and Potato-raising Plough. (*Hornsby.*)

FIG. 11.

and alone for earthing-up purposes. The marker is set to whatever breadth of drill is required and the mould boards are adjustable within limits. The potato plough is used to plough out the potato crop at lifting time. Although it is light in draft it is disadvantageous in that the potatoes may be partly buried and more labour is required for gathering; it is probably less damaging to the tubers than any other form of lifter.

Cultivating, Harrowing, and the Control of Weeds.

In this section cultivating and harrowing are treated together because their effects are the same in principle. There is no hard-and-fast line between the two types of implements, but as a rule cultivators are mounted on wheels and harrows have no such fittings. Apart from the numerous types of harrows, the implements of cultivation vary greatly and include hand-hoes, horse-hoes, scufflers, grubbers, spring-tine cultivators, steam and tractor cultivators, all of which differ markedly from the plough in that they neither invert the soil nor cover over vegetation and manure, but tear up the ground and break its adhering masses asunder. From a general point of view cultivation effects a marked improvement in the soil by its promotion of drainage and aeration, its redistribution of plant foodstuffs and manures, and its encouragement of micro-organisms. But the chief objects of cultivation are (1) to reduce the soil to a fine "mould" or "tilth," (2) to destroy weeds, and (3) to control the rise of soil moisture.

In the formation of tilth the tined implements can seldom be employed alone, but must be used in conjunction with the plough and the roller. In soils of the lighter class ploughing may suffice to reduce the seed-bed to the necessary fineness; but ploughing is a slow operation, and the use of the cultivator, which covers the ground far more rapidly, usually proves more economical. In the formation of a mould it is customary first to level the field by harrowing, or, if the soil be sufficiently dry, by harrowing

and rolling. The tilth may then be gradually deepened by using heavier implements for each successive operation. However, the nature and sequence of the operations depend on the texture and moisture content of the soil, and in some cases it may be better to employ the heavier cultivators first with the object of breaking up the large clods, and to follow on with lighter and lighter implements as the fragments of soil become smaller and smaller, the final condition of the tilth being determined by the size of the seed to be sown. In all cases small seeds—*e.g.* turnips and grasses—demand a fine tilth and shallow planting, while large seeds can succeed in a bed of correspondingly greater coarseness and may even be ploughed in. Land should never be worked too fine for autumn and winter sown crops, or it will be liable to run together under the influence of rain, and set into an intractable layer whenever it dries.

Where the length of the season permits, as in all except the northern districts, the work of destroying weeds by means of the tined implements should commence on the stubbles immediately after harvest. When cultivators are employed they should not be worked too deeply, but should be fitted with paring shares and set so that they cut the weeds off an inch or two below the surface and leave them lying exposed to the sun. The land may afterwards be harrowed to prevent any of the plants from getting a fresh hold, and in the case of a weed like couch-grass, which cannot be killed by ordinary uprooting and exposure, chain harrows should be employed to roll the material together so that it can be removed or burned. Another object of cultivation at this time is to produce a fine surface tilth which will encourage the germination of any weed seeds that may be present, and render them easy of destruction by further operations. As the time is limited during which operations of this kind can be performed with a maximum of effect, the use of tractors is well worth consideration because of the speed with which they get over the ground, and on account of the long hours they can be worked. Some farmers, after they have completed the cultivation of their

stubbles, draw the land up into ridges by means of three-row ridging machines, and leave it in this condition throughout the winter. They claim that the greater surface exposed in this way leads to a more complete germination of the weed seeds, that the soil is set up so that it receives a maximum of benefit from frosts, that the furrows facilitate drainage and surface drying, and that the land warms up more readily and can be more quickly worked into a seed-bed in spring.

Spring cultivations for the destruction of weeds consist most largely of the use of harrows and horse-hoes for the cleaning of the land between the rows of autumn sown cereals, and, in the case of late sown crops like turnips, a repetition of the autumn operations of cultivating, ploughing, and dragging.

The control of weeds for the rest of the season consists in the horse and hand-hoeing of root crops, and the spudding and pulling of weeds in corn, the work in the root crops being the more important. Potatoes should be kept clean by harrowing down the ridges, horse and hand-hoeing, and earthing up, the operations being repeated as often as necessary. Turnips and mangels should be scarified, hand-hoed and singled, and horse and hand-hoed as often as is essential to keep the land clean. Only too often the number and sequence of root cleaning operations are fixed by local custom without regard to the condition of the soil. The cleanliness of the land alone should decide the operations, and, as the thoroughness of the cultivation of the fallow crop usually determines the state of the land for the rest of the rotation, the work must be carried on as long as weeds grow, even if a certain amount of damage—which is usually more apparent than real—is occasioned to the plant foliage.

The effect of cultivation on the control of soil moisture is of very great importance. If the land is left compacted or rolled, the surface tension brought about by the close proximity of its particles causes a rise of water from the subsoil to the surface. This may be ideal for certain purposes, but in time it brings about a considerable loss

of water through evaporation and exhausts the subsoil reserves. Cultivation, however, has the opposite effect; it loosens the upper layers of the soil, thereby increasing the air spaces, and by interrupting the capillary passages cuts off the rise of moisture. The loose mulch therefore brings about a considerable conservation of water, which remains available for absorption by plant roots. Mulching is regularly practised and is of vital importance in most countries of low rainfall. Again, as the water, air, and temperature of a soil are so intimately related to its pore space, which is increased by cultivation and decreased by rolling, it is possible by judicious working of implements to influence these important factors in soil fertility, bearing in mind that looseness means high temperature and little water, and that over-compaction reduces the amount of air and lowers the temperature.

Harrowing stirs the soil like cultivating but to a lesser depth. Harrows, which correspond to rakes in horticulture, can be used for the formation of a mould, for covering over seeds, for breaking up caked land surfaces, for dragging out weeds in arable and moss in grassland, and for the distribution of droppings and manure. The use of moderately light harrows for checking evaporation is usually better than the employment of cultivators, which are inclined to work the soil too deeply. Moreover, harrows can often be used on growing crops without fear of the plants being uprooted.

Types of Cultivators.

The Scuffler.—Fig. 12 illustrates a type of cultivator such as is used to perform many of the heavier acts of tillage. Implements of this type are somewhat heavy in weight and draft, but they are very strong, and can be used to perform rough work without fear of derangement. Their iron construction gives them the weight they require to force themselves into the ground; they usually have a 4½ ft. cut, and require two or three horses according to the depth to which they are worked and the condition of the soil.

They may be used to break up land that has lain in the furrow throughout the winter, to level land that has been

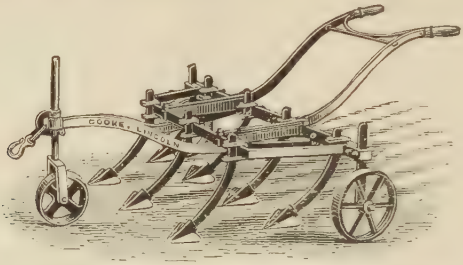


FIG. 12.—Scuffler or Heavy Cultivator. (*Cooke.*)

tracked by the carting off of roots, for summer fallowing, stubble breaking, etc. The depth of the work is varied

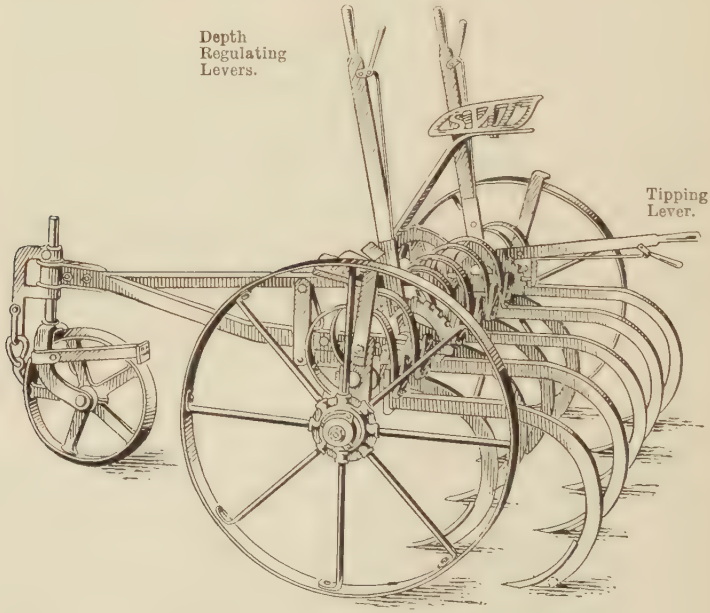


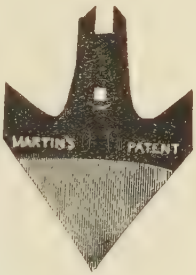
FIG. 13.—Martin's General Purpose Cultivator.

by moving the wheels up and down in the sockets; but some implements of this type are fitted with ratchet levers which

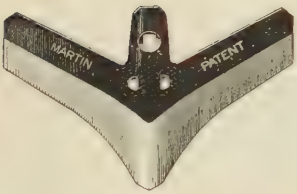
allow the wheels to be raised or lowered instantly. Still other implements have self-lifting gears of a pattern similar to that of a tractor plough, and can be used with agricultural motors as one-man outfits.

The Spring-tine Cultivator.—Martin's general purpose cultivator of the spring-tine type is illustrated in Fig. 13.

Hard Ground.



Soft Ground.



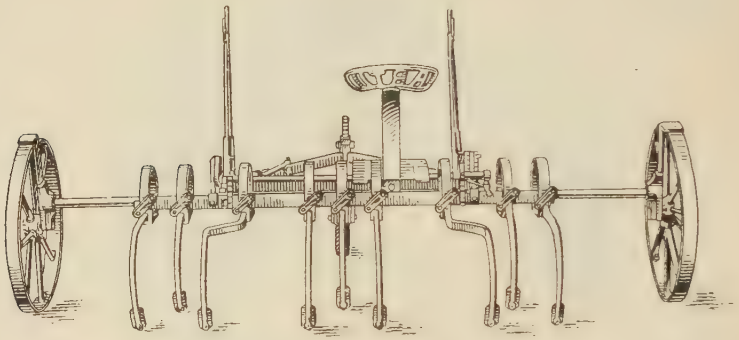
Skimming.

Thistle Cutting.

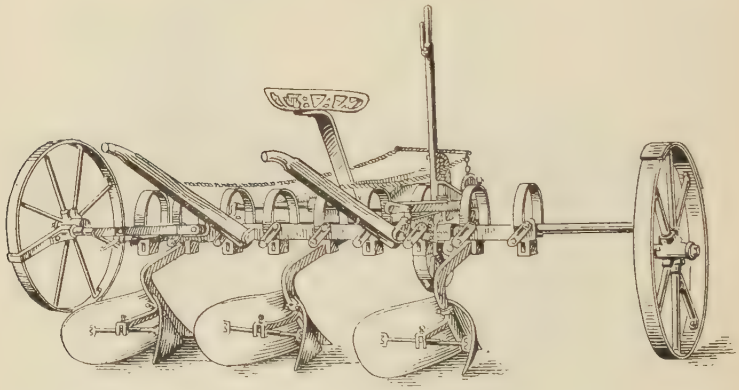
FIG. 14.—Types of Cultivator Shares.

In this machine the tines are not rigidly attached to the framework, but are connected by flat steel springs, which by giving a little when the tines hit a large stone or obstruction allow the shares to override it; moreover, the spring gives the tine a slight vibratory motion which is said to produce a finer mould. Machines of this type do not depend on dead weight to force the tines into the ground, but the carefully adjusted angle of the share causes it to draw into the soil,

and there is no doubt that the lesser weight and the give and take action of the springs greatly reduce the draft. The shares are of steel and can be removed from the tines and renewed when they become worn, and different types of shares (Fig. 14) can be fitted so as to obtain a maximum of



Martin's machine as 3-drill grubber.



Martin's machine as 3-furrow ridger.

FIG. 15.

effect from any particular operation; but it should be understood that the broad shares, which are designed for the destruction of weeds, can only be used for shallow working.

Not only can a machine of this type equal the ordinary scuffler for many purposes of cultivation, but it has an

undoubted advantage in that it may be converted into an implement for the cleaning of root crops and for the drawing and splitting of ridges (Fig. 15). These changes can be brought about because of its adjustable track, its removable and adjustable tines, and the special double mould board bodies that are provided for fitment to the frame. The illustration of the machine in its different forms is self-explanatory, but it should be noted that the lateral adjustment of the wheels, tines, and bodies allows the machine to

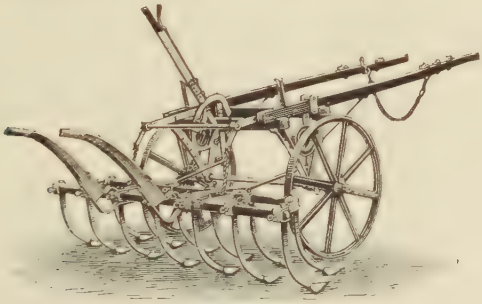


FIG. 16.—Steerage Horse-Hoe. (*Cooke.*)

be set for any breadth of drill. The depth of working is controlled by ratchet levers which are connected to the eccentrically mounted wheels.

The Steerage Horse-Hoe.—The machine in Fig. 16 is a one-horse steerage hoe, consisting of a wheeled fore-carriage and a trailer body which carries the tines and the steering handles. The implement is primarily designed to hoe between the rows of a cereal crop; its tines can be set to suit any distance between the drills, and the handles allow of its guidance through crops that have been drilled somewhat irregularly. The wheels can be moved to any position on the axle, so that they may be set to avoid overriding the plants, or to fit in with the size of the drills when the machine is used for horse-hoeing roots. This type of implement is extensively used for cleaning root crops that are grown on the flat, but it is of course necessary to use different shaped tines for roots and corn.

The Drill Horse - Hoe. — Drill horse-hoes, harrows, cultivators, and grubbers are implements designed for cultivating between the rows of root crops during the growing season. The expanding type of horse-hoe, illustrated in Fig. 17, consists of a frame, the side members of which are hinged in front, and can be fixed to give any desired width of cut by means of a clamping screw acting on the rear cross members; it is kept in balance by means of its handles, and its depth of working is controlled by moving the wheel up or down in its socket. Horse-hoes vary in size and weight; heavy two-horse implements are

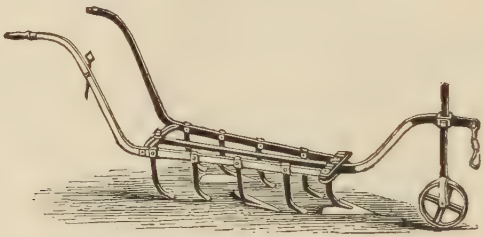


FIG. 17.—Expanding Horse-Hoe. (*Cooke.*)

made which allow of deep work, and on the other hand, light five-tine hoes can be obtained suitable for market gardens. Types of hoe-blades are manufactured to suit all soils and crops.

Types of Harrows.

The Zigzag Harrow.—Zigzag harrows (Fig. 18) are of the ordinary type with fixed vertical tines, and are constructed in many different sizes and weights. The lightest type, which, however, may have a very broad track, is used for covering over grass seeds, and consists of a light wooden framework with very short iron teeth; it takes the place of the old-fashioned brush harrow for the lightest class of work. The heavier makes have iron frames and longer tines, so that they have a greater penetration in hard land; their

track is 7 ft. 6 in. to 9 ft., and all but the heaviest makes can be drawn by two horses.

An improvement on the ordinary harrow is an implement fitted with hinged teeth, the set of which is controllable by means of a tilting lever. Such an arrangement allows of a forward setting of the tines, which enables the implement to work to a greater depth if the land is hard, and, if the surface is strewn with dead weeds, a backward setting to avoid clogging of the teeth and loss of efficiency.

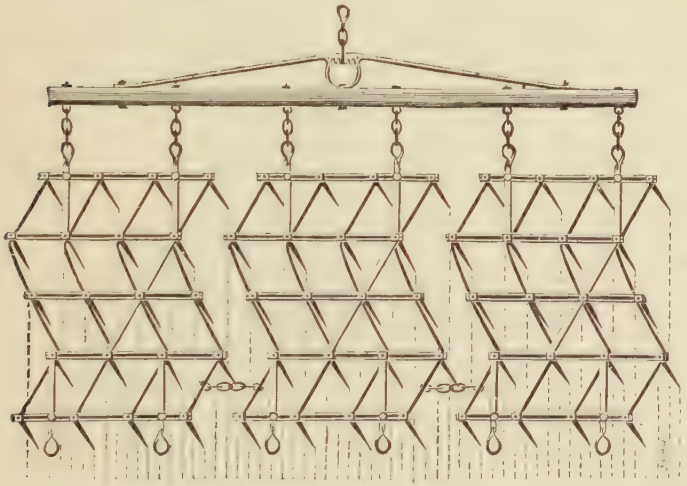


FIG. 18.—Ordinary Zigzag Harrow. (*Sellar.*)

The Drag Harrow.—Fig. 19 illustrates an ordinary type of drag harrow. An implement of this kind has usually a 6-ft. track, and is intermediate between a harrow and a cultivator in its action. The long tines with their forward curve penetrate a considerable way into the soil and create a fairly deep tilth. This harrow is very largely used for dragging out creeping weeds like couch-grass, and it is fitted with handles, so that it may be raised from time to time during its working and freed from rubbish.

Spring-toothed Harrows (Fig. 20) have an action somewhat similar to that of drags, but the angle of the spring tines

can be instantly altered to suit the condition of the land or, when used for weed dragging, to free the implement from trash.

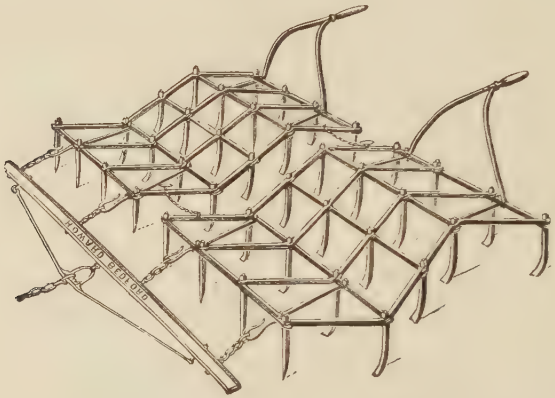


FIG. 19.—Drag Harrow. (*Howard.*)

FIG. 20.—Spring-tooth Harrow. (*Sellar.*)

The Chain Harrow.—Chain harrows are constructed of link pieces, which may or may not carry small tines, and are completely flexible. They are most largely used for spreading droppings, mole-hills, etc. on grassland, but they

may be employed for harrowing down potato drills and rolling together the dead weeds on fallows.

The Disc Harrow.—This implement, which is illustrated in Fig. 21, is probably the most efficient type of harrow for pulverising and loosening the soil. Not only is it used for the creation of a tilth on ordinary arable land, but it may be worked on grassland to cut up the surface and promote aeration, or in preparation for manuring and regeneration. No other harrow can work so well on soddy land, as the rolling action of the discs precludes all possibility of clogging. Moreover, the discs have a slight digging and soil turning action, and may be used

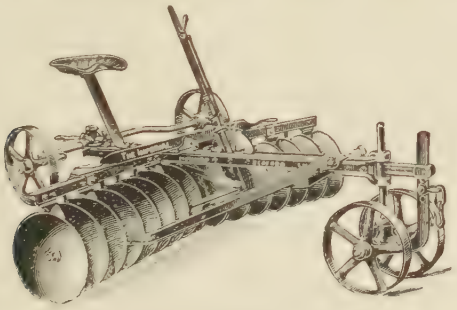


FIG. 21.—Disc Harrow. (*Howard.*)

for the destruction of weeds that have got beyond the control of ordinary harrows.

The machine consists of two gangs of discs attached to a framework which carries the shaft and driver's seat. The gangs are hinged, and the angle they make with the line of draft can be varied, according to the nature of the work required, by means of ratchet levers; but the balance of the machine is maintained because the drag from one set of discs is counteracted by the drag from the other discs, which are curved in the opposite direction. The penetration of the implement into the ground is determined by the angle of the gangs with the line of draft, the curvature of the discs, the weight of the harrow, and the sharpness of the blades.

The Control of Weeds.

The eradication of weeds is so intimately associated with the cultivation of the soil that it is advisable to consider the various methods of control before proceeding further.

What is a weed? From the farmer's point of view it is a plant that competes with the cultivated crops for the goodness of the soil and the energy of the sun's rays, and is itself useless to him. The presence of weeds in arable land invariably results in a reduced yield (which in the case of cereals may be as much as 50 per cent.) and in a lesser profit per acre. Moreover, in the case of grass-land, not only is the amount of valuable fodder diminished, but its palatableness may be so injured that it is neglected by stock. The effects of weeds may be summarised as follows: (1) They reduce the yield of the crop by their absorption of foodstuffs and moisture from the soil. (2) They utilise the energy of sunlight, and when they are growing strongly may smother the cultivated crop to such an extent as to render it incapable of satisfactory growth. Perhaps this kind of damage is best seen when weeds, competing with slow growing seedlings—*e.g.* carrots—so completely overrun the land that the crop is lost and has to be ploughed in; or, in the case of turnip and mangel seedlings, the smothering may be so great that it is practically impossible to pick out the plants in singling. (3) They harbour and propagate worm, insect, fungus and bacterial pests, and neutralise much of the benefit arising from a strict rotation of crops. (4) The presence of weed seeds in samples of cereals, grass seed, etc., greatly detracts from their market value, and considerable pecuniary loss may follow if grain that is otherwise fit for sowing has to be sold for milling purposes. (5) When certain weeds—*e.g.* garlic—are eaten by cows they transmit undesirable flavours to the milk and milk products, which may thereby be rendered unsaleable. (6) They greatly reduce the market value of land because their presence necessitates

the provision of considerable capital for their control and eradication.

How does land become infested with weeds, and how are they propagated from year to year? Many seeds—*e.g.* the tiny seeds of the poppy and the fluffy seeds of the Compositæ—are so small that they are carried for great distances by wind; some are carried because of the adaptations which cause them to adhere to the coats of animals and birds, and some are eaten and voided without being injured by the processes of digestion. Weeds may be carried to the land in dung, which has been made from straw that has been improperly cleaned in the threshing process. Consequently it is of the greatest importance that the thresher should be set so that it delivers clean straw and chaff, and the weed seeds and rubbish left on the ground after a day's threshing should on no account be thrown into the courts but should be burned. Although weeds may be introduced in purchased dung they are far more frequently obtained in impure seed, and the farmer should refuse to take delivery of samples containing harmful weed seeds, or more than a very small proportion of the less objectionable sorts. Weeds are spread on the farm by means of seeding and vegetative reproduction. For example, charlock is spread and propagated by the scattering of its seeds in the ordinary way, but couch-grass will overrun light land by the rapid growth of its creeping stems. How long do weeds remain in a condition capable of growth? Some seeds—*e.g.* charlock—have been known to lie in the ground for tens of years under grass and have grown in abundance in the first following cereal crop, but most seeds probably die off in three to eight years.

Methods of Eradication.—The most obvious method of ridding the soil of weeds is to drag them out or cover them deeply by means of the implements of cultivation. It is, of course, essential to obviate all possibility of the weeds seeding, and with this in view the work should be carried out before seed formation commences, as ripening may take place after the plants are cut. Weeds should be attacked when

they are weakest, *i.e.* at the cotyledon stage, when, having used up the reserves of food in their parent seeds, they are yet insufficiently developed to make much use of their own synthesising powers. No object is served by allowing the weeds to attain a considerable size, because they are then more difficult to uproot and more likely to obtain a fresh hold. Cultivation in bright, sunny weather will generally be found to be most effective because the weeds wilt rapidly and die; on the other hand, a shower of rain will often nullify the work of many hours by supplying the uprooted plants with moisture, thus facilitating their re-establishment.

Not only should weeds be suppressed on arable land, but seeding should be prevented in adjoining roadsides, coverts, and waste places, which are likely to be continual sources of re-infection.

Cultivation, however, is also employed to bring about the germination of seeds with a view to their future destruction. If weed seeds have shaken on the ground—as is generally the case after harvest—the best treatment is to work the land to a very fine surface tilth, which, in conjunction with the warm, damp autumn weather, causes the majority of the embryo plants to spring into life and allows of their eradication.

Under certain circumstances weeds that have established themselves strongly have to be dealt with. Perennials because of the reserves of food in their roots must be considered in this class. There is little doubt that hand pulling and digging are the best methods for their removal, but the cost is often prohibitive. However, if the horse workings of a crop like potatoes are supplemented by the hand pulling of plants like fat-hen and thistles, the land can almost certainly be thoroughly cleaned. Digging is sometimes necessary. Bulbous oat-grass, for example, can only be got rid of by forking it out. The persistent cutting of perennials with hoes, spuds, or scythes will ultimately destroy them by exhausting their food reserves and undermining their vitality; but too often they are subjected to

one cutting only, which simply stimulates them to branch and increases their powers of seed production. Thistles may be got rid of in two seasons by cutting them two or three times; but in the case of bracken, which has very large reserves, the cutting may have to be repeated for three or four seasons if it is to prove efficacious.

The greatest difficulty occurs in the eradication of weeds like couch-grass and docks, which are capable of producing fresh shoots if even a small portion of the stem or root is left in the soil. Here it is no question of killing tender seedlings, but a case of destroying established perennials which exhibit astonishing vitality, and the treatment must necessarily permit of their removal without breaking them up in the soil. Docks cannot be destroyed by the ordinary implements of cultivation, as they possess very deep tap roots containing large reserves of foodstuffs; they must be forked out of the ground, removing as much of the root as possible, and carried off the field, as they are seldom killed by exposure on the surface; they must be removed at once and completely destroyed, or they will spread rapidly and become almost ineradicable. In the case of couch-grass and creeping thistles the plants must be dragged to the surface with cultivators and drag harrows, allowed to dry, raked together, and carted off or destroyed by burning. It is difficult to uproot couch without breaking the plants, but in autumn, when the land is somewhat soft, an almost complete removal may be effected by the use of drags or spring-tine harrows, although the carting off of the weed will be more than usually laborious because of the amount of soft soil that adheres to the roots. In the case of foul strong land, it may be best to plough in May and kill the couch in the clod by summer cultivations.

The weed flora of the soil can be considerably modified by means of drainage and irrigation. It is well known that pasture land may be cleared of rushes and sedges by the introduction of drains to remove the excess of moisture. On the other hand, when land can be irrigated with hard water, a complete suppression of the acid-loving herbage

may be brought about. On hill pastures spring water may be diverted and spread through a system of shallow grips. When this is done heather and other "black hill" plants die out and are replaced by useful grasses. Again, it was found at Cirencester that the irrigation of ordinary meadow land will free the soil of bulbous buttercup, tufted hair grass, and broad leaved plantain in a few years.

It has been pointed out before that sourness is indicated in arable land by the presence of sorrel, spurry, and marigold, and in pastures by bracken and sorrel. It is therefore possible to check these weeds by the judicious application of lime.

An important method of checking weeds is the growing of really heavy and luxuriant crops. If sufficient foliage can be developed completely to shade the ground, it is impossible for weeds to grow. Such crops are sometimes termed "smother crops," and in ordinary farm practice, potatoes, vetches, rye, and good wheat and oats have a considerable smothering effect; probably, however, the finest crop for this purpose is kale. If either marrow-stemmed or thousand headed kale is sown in rows, and the ground is kept horse-hoed until the plants have attained a good size, the crop will grow so tall and strong that a complete shade is cast and weed growth is severely checked. Rape, maize, and "mashlum" have been recommended as smother crops, but rape does not produce as much foliage as kale, and maize can only be grown in the southern districts.

Some pasture weeds can be kept in abeyance by careful management. As yellow rattle and Yorkshire fog ripen and cast their seed early, they tend to increase where meadows are mown at the usual time; but if the land is grazed so that the reproductive shoots are kept in check, seeding and reproduction are largely prevented. As sheep eat yellow rattle greedily they should be employed when the checking of the weed becomes necessary. Bent grasses, which infest and deteriorate so many boulder clay pastures, produce their seed late in the season, and it is therefore possible to check their reproduction by mowing the herbage for one or more

seasons, or, if the land is required for grazing, a high-set mower may be used to cut off the immature flower heads. In all cases, judicious manuring may be relied upon to keep weeds in check by encouraging the development of clovers and good grasses.

Spraying is a modern method of weed eradication. The best-known spraying treatment is the destruction of charlock in growing corn by the application of at least 50 gallons of 4 per cent. copper sulphate to the acre. In this case the broad, rough leaves of the cruciferous weed retain the wash, which is toxic, and kills the tissues, while the solution drains off the smooth upright leaves of the cereal without causing any serious damage. To get the best results the weeds should be sprayed when they are about 3 in. tall, but if they are completely sheltered by the corn they may be allowed to grow further. A calm, dry day should be chosen for the work, as a fall of rain greatly interferes with the efficacy of the application. In a few hours the weeds will have a blackened appearance. Sometimes a 15 per cent. solution of sulphate of iron is used for charlock spraying, and sulphate of ammonia and kainit have also been employed for weed killing with a certain amount of success. A 5 per cent. solution of sulphuric acid has been used effectively for the eradication of bracken.

Many types of spraying machines are in use, varying from small knapsack appliances to large horse-drawn vehicles with mechanical pumps, but the principle of working is the same throughout. The solution, which, in the case of copper sulphate, should be mixed in wooden barrels, is placed in an air-tight container and led to the spraying nozzles through flexible piping. An air-pump is employed to increase the pressure in the container, and the solution is forced through the nozzles with considerable velocity and breaks up into a very fine misty spray which finds its way on to practically all the leaf surfaces.

Rollers and their Uses.

The objects of rolling are to level the land surface, to break down clods and develop a tilth, and to encourage the rise of moisture by consolidating the surface soil.

When rolling is practised with the object of breaking down clods it is frequently performed after cultivation, which pulls many of the large lumps of earth to the surface and leaves them placed in such a way that they are easily crushed. When clods are very difficult to break, heavy rollers of small diameter and clod-crushing Cambridge or Crosskill rollers will be found to be most effective. It need hardly be stated that the act of rolling will bring about a levelling of the surface which may be very desirable for the broadcasting of small seeds.

The use of the roller for the control of soil moisture is most important. It has been pointed out that stirring the surface of any soil interrupts the rise of moisture and minimises the loss of water by evaporation. Rolling has exactly the opposite effect; it brings about a compaction of the particles which reduces the interstitial spaces, increases the surface tension, and causes the capillary moisture to come to the surface. Rolling is therefore particularly necessary on light and chalky soils where seeds have difficulty in obtaining sufficient moisture for their germination and healthy growth, and the heaviest rollers are used on this type of land. Nevertheless, while it is necessary that moisture should find its way to the surface until the crops have become established, leaving the ground in a rolled condition does not benefit plants that have a good root hold, and a time comes when evaporation should be checked by the development of a surface mulch. Perhaps the best general rule to follow is to keep the lower layers of the soil well compacted by rolling so that they remain moist, and to keep the upper layer well stirred to check evaporation.

Spring rolling is generally practised on cereals that have been growing throughout the winter, and on grasslands,

in order to remove the ill-effects of frost (which is liable to throw the plants out of the ground) by packing the soil about the plant roots. Care should be taken to avoid rolling heavy land when it is wet, as there is a danger of the soil being "poached." Other uses of heavy rollers are to check the ravages of wireworms, to flatten down tall green-manuring crops so that they may be more easily ploughed in, and to remove lumps which might interfere with mowing.

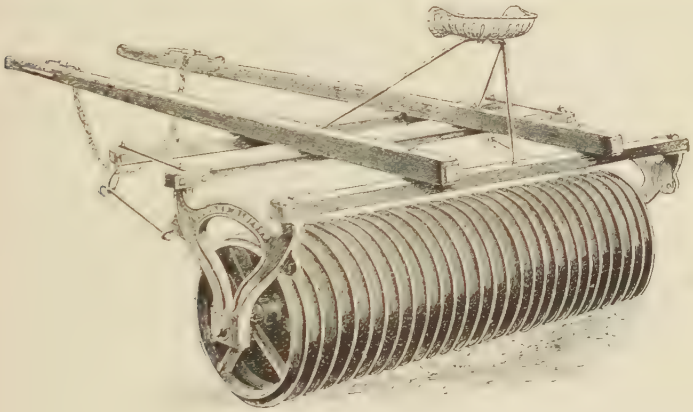


FIG. 22.—Cambridge Roller. (*Howard.*)

Rollers.—Rollers vary in diameter, width, weight, shape, and the materials of which they are constructed; they are manufactured to suit all ordinary and special purposes. Probably the heaviest and most effective rollers that are in use are the stone rollers, still seen in many quarrying districts. As the material is so exceptionally heavy these rollers have to be made small in diameter, and consequently they exert an enormous crushing effect; as, however, their draft is particularly heavy, their use is generally confined to bad years, when a tilth is difficult to prepare. The most common rollers are constructed of iron, in the form of cylinders mounted on a long axle, the division into sections allowing of more easy turning at the headlands. Sometimes a single cylinder water-tight barrel is used which can have

its weight increased by the addition of water, the weight being determined according to the nature of the work to be done. The heaviest iron clod-crushers are Cambridge (Fig. 22) and Crosskill rollers, the former being built up of heavy ribbed and the latter of heavy toothed sections which reduce the bearing surface on the ground and exert more pressure on the lumps of earth. Small rollers (Fig. 23) for a single horse are fitted with shafts, but large two- and three-horse sizes have a framework and one or two wheels to support the hitching gear. When rollers of the latter type are used on hilly farms they must be fitted with brakes in order to avoid serious accidents. Light

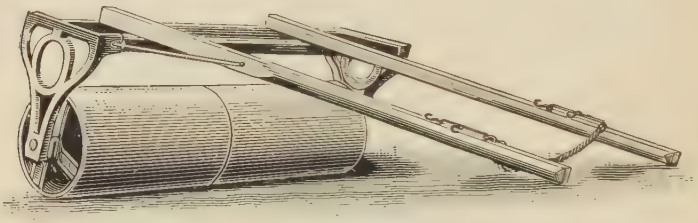


FIG. 23.—Plain Roller. (*Sellar.*)

one-horse rollers are frequently made of wood, either in the form of a turned log or built up from staves; they are useful for light work, but have little value for crushing purposes. When it is desired to increase the weight of light rollers, iron cart axles and heavy stones may be securely fastened to the framework. Special rollers are made in the form of dished iron cylinders for rolling turnip drills. These are particularly useful in producing the consolidation necessary to bring about the germination of the seed in a dry spring.

The Sowing of Seed and the Spreading of Manures.

Seed may be sown by broadcasting, dibbling, drilling, or ploughing in. The most suitable method for each of the farm plants is considered under the heading of "Crops." Drilling

is the most modern method, and under most conditions the most economical. Land must, however, be in fairly dry condition before drills can be worked satisfactorily, and in late seasons and on heavy land an earlier seeding may be rendered possible by broadcasting. More seed per acre may be necessary when broadcasting is practised, and horse-hoeing is seldom possible in a crop seeded in this way; but the land is more completely covered by the crop and a greater smothering effect is secured.

Broadcast Sowers. — Different types of broadcasting machines are available for scattering different kinds of seeds. On many farms cereals are broadcast by hand from a sowing-sheet or hopper, machines being used for the distribution of grass and small seeds only; but in the southern districts hand-sowing is less common, mechanical distribution being the rule. Most machines consist of a wheeled and shafted framework carrying a long seed-hopper, mounted at right angles to the line of draft. The seed delivery apparatus, which may be in the form of brushes, cups, or pinion wheels, is mounted on a shaft which rotates in the bottom of the hopper and passes the seed out and on to the ground through delivery holes or ports. The ports, which are placed at short intervals across the machine, can be adjusted to various sizes according to the type of seed and the weight that is required per acre.

Drills.—A modern type of disc drill is illustrated in Fig. 24. The hopper and feed parts of a corn-drill are very similar to the corresponding structures in the broadcasting machine, but the drill is fitted with extra parts which conduct the seed from the delivery ports and bury it in the soil. Conductors of flexible steel ribbon receive the grain as it leaves the hopper, lead it to the grooves made in the soil by the passage of the coulters, and leave it at such a depth that it is immediately covered over by loose earth; but sometimes, as in the case of the machine in the illustration, light chain harrows are attached to make the covering more complete. The coulters are kept in the ground by means of weights on the coulter press levers or by the pressure

of coil springs, and the depth is varied by adjusting the weights or altering the spring pressure. In some machines the delivery ports are not variable, and different rates of seeding are obtained by the employment of different sized pinion wheels in the drive from the wheels to the delivery gear. On most drills the coulters have a certain range of lateral adjustment which allows of the drills being made at any required distances apart, and for drilling roots on the

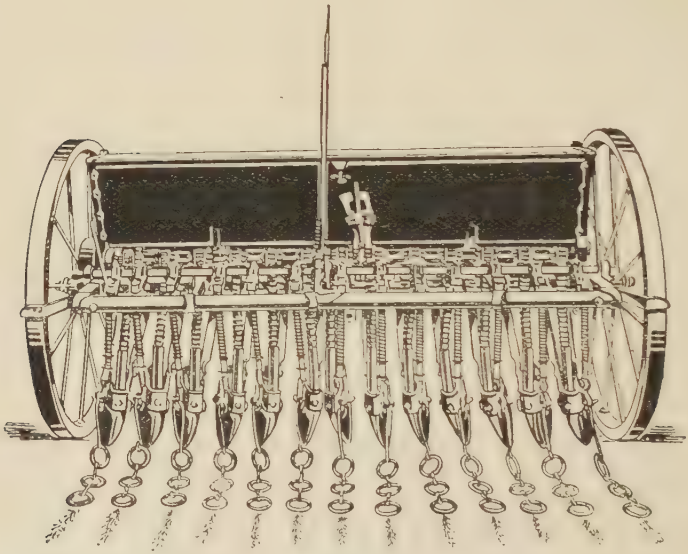


FIG. 24.—Hornsby Disc Grain-drill.

flat all but four coulters may be removed and their delivery ports shut off. A clutch is fitted for engaging the delivery gear, and a ratchet lever enables the coulters to be raised clear of the ground for travelling purposes.

Turnip and Mangel Drill—Fig. 25 illustrates a special type of drill designed for sowing root crops on ridges. The moulded rollers serve to consolidate the ground before the seed is deposited, and flat rollers can be obtained for fitting behind the coulters to counteract their loosening effect. Sometimes machines of this type are fitted up so that they

can deposit water, liquid manure, or artificial fertilisers with the seed.

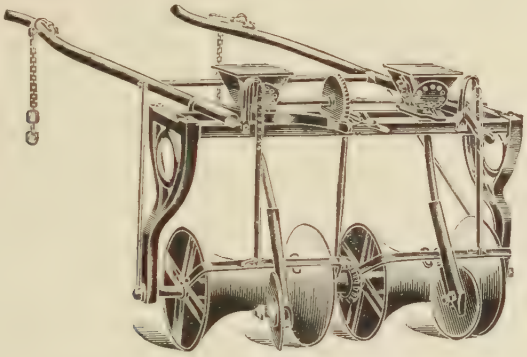


FIG. 25.—Turnip and Mangel Sower. (*Sellar.*)

Manure Distributors.—A great variety of machines are available for the distribution of artificial fertilisers; for large applications they are more economical than hand distribution, and they are certainly more conducive to the comfort of

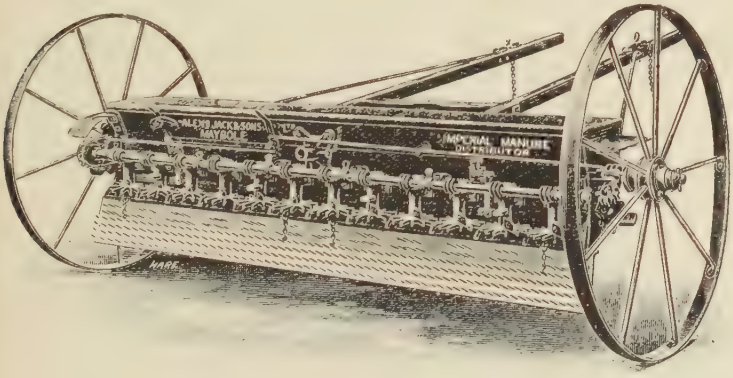


FIG. 26.—Manure Broadcasting Machine. (*Jack.*)

the operator. Some machines employ a centrifugal distribution by means of rapidly revolving horizontal discs; some have a cup feed similar to seed sowers but on a bigger scale, and others have endless chains carrying scrapers which

remove the material from the hopper and cause it to fall to the ground. The implement illustrated in Fig. 26 has scraping fingers mounted on revolving spindles which deliver the manure from the bottom of the hopper; its rate of discharge can be regulated by changing the speed of the spindles (by the introduction of different gear wheels) and to some extent by increasing or decreasing the size of the delivery slot. The wheels can be transferred to a cross axle and the shafts fixed to one end of the machine so that the track is reduced to a few feet, and the implement can easily be taken through gates, etc.

Special manure spreading machines are constructed with two or three spouts for the deposition of fertilisers in the bottoms of potato and turnip drills.

Liquid manure is transported in tanks mounted on cart frames, and distributed by allowing the liquid to flow into perforated trays which are placed across the back of the machines.

Farmyard manure spreaders are constructed in the form of low four-wheeled wagons, with false creeping bottoms that carry the load towards the mechanical forks or kickers situated where the tail board normally is. These machines are entirely mechanical, and the energy by which they empty themselves and scatter the dung is transmitted from the rear wheels through suitable gearing. They require three horses or a tractor for their draft, and the average time taken to spread a load (about 1 ton) at the rate of 14 tons per acre is five minutes.

The Cutting of Crops.

Except for very small acreages, or for badly laid cereals, the scythe is now seldom used in the cutting of crops. It has been almost entirely superseded by the mower for cutting hay and forage crops, and by the reaper or binder for harvesting cereals and beans. A few crops, however, do not lend themselves to the use of modern implements; peas are best cut with a hook or pulled out of the ground, and

flax, because of its long and valuable fibre, is usually hand pulled.

If neatness is aimed at, and labour is available, the scythe may be used to open "roads" round the fields so that the horses may not trample nor the implements crush down any of the crop, but this is neither absolutely necessary nor especially advantageous as a preliminary to mowing. Where tractors are used for the draft of harvesting implements it may be necessary to keep a man in the field to round off the corners of the crop with a scythe, because these machines cannot make a clean right-angled turn.

The use of a high-speed mower produces the most thorough cutting, and leaves the shortest stubble. Such a machine can usually deal with a "lodged" crop. Next best is the reaper, with which it is sometimes possible to harvest leaning corn where the heavy, slow binder would produce a poor finish and leave the stubble too long. A good upstanding crop can be cut round and round with any harvester, but when strong winds have given the corn a pronounced lean in one direction, cutting two ways, or even one way only, against the bend, may be necessary. Every farmer uses his own discretion in the choice of implements, and, by reason of its economy in time and money, uses the binder for cereals whenever feasible.

The Mower.—The modern two-horse mower (Fig. 27) consists of a framework mounted on two wheels, suitable gearing to transmit the power from the wheels to the cutting apparatus, and a cutter bar containing a reciprocating knife. The shaft is mounted on the frame, and when the driver occupies the seat the machine is well balanced. The gearing, which may be taken from one or both wheels, is high-speed, and the bearings are ball, roller, or plain, according to their positions. A dog clutch is provided to put the mechanism in motion, and is disengaged for convenience in travelling. The cutter bar may be either on the near or the off side of the machine; its usual width is $4\frac{1}{2}$ or 5 ft.

The cutting apparatus consists of a long bar furnished with projecting fingers, the function of which is to steady

the herbage while it is being cut by the knife, and to prevent the knife from entering the ground and being damaged. The fingers are slotted horizontally to allow of the insertion of the knife and its movement to and fro. The knife consists of triangular steel knife-sections riveted to a steel bar. The rivets are easily punched out, and new sections can be inserted when the old ones are worn or damaged. The knife is retained in position by steel clips and moves over

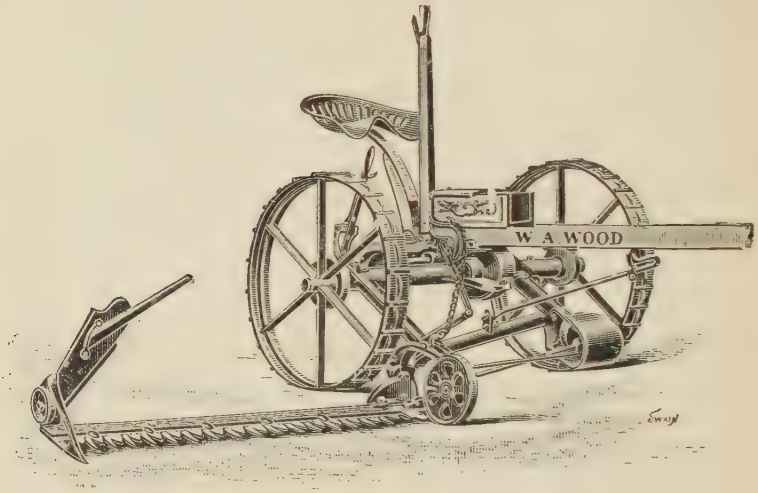


FIG. 27.—Hay Mower. (*Sellar.*)

hardened steel wearing-plates, which reduce friction in a piece of mechanism that is difficult to lubricate. At the end of the cutter bar is an adjustable swath-board which rolls the cut herbage to one side in the form of a swath, and leaves a clear track behind the machine. A very small wheel is placed behind the swath-board to take the weight of the cutter. A tilting lever is attached to the bar which allows of very close cutting when the ground is smooth, and of elevation of the fingers when stones or unevenness of surface renders close setting undesirable. The whole of the bar is hinged, and can be moved into an upright position for travelling.

The Reaper.—The reaper is designed on the same principles as the mower, but it is adapted for cutting taller crops, and is usually complicated by the addition of a self-delivery apparatus.

The simplest reaper has a short platform behind the cutter bar on which the corn is allowed to gather as it is cut, and from which, as soon as there is enough to form a sheaf, it is dropped by depressing the platform through the agency of a foot lever.

Some reapers, however, are of the side-delivery type, and are provided with large platforms and revolving rakes and gatherers. As the machine advances, the gatherers, which take the place of the reel on a binder, draw the corn towards the knife and cause it to fall back on the platform, and the rakes sweep the material backwards and to one side so that enough corn is delivered on the ground to form a sheaf. The sheaves have, of course, to be bound by hand.

Apart from the self-delivery apparatus, an important difference between a reaper and a mower is the construction of the divider at the end of the cutter bar. As corn grows considerably higher than grass, the reaper divider is much bigger and is followed by a large wheel to carry the weight of the platform; it is very similar to the outside divider on a binder.

The Binder.—The modern reaper and binder (Fig. 28) is the outcome of many years of patient investigation and experiment, and no single man can claim the honour of being its originator.

The frame of the machine is made almost entirely of steel, and is well braced, so that it is both light and strong. The main driving-wheel, which is carried in the frame, has to be made very strong and supplied with roller bearings, because it carries most of the weight and is subjected to severe strains. When the machine is started up the power is taken from the driving-wheel by a strong chain to a roller-bearing crank, and thence, through a dog clutch, by means of gearing and chains, to the various revolving and oscillating parts of the mechanism.

A steel platform, strengthened by cross bars, is riveted to the frame, and supported at its free end by means of a grain wheel. The cutter bar, which is commonly 5 or 6 ft. broad, is situated in front of the platform, its structure and action being similar to those of the mower. In order to prevent the grain wheel overriding a portion of the corn, a wedge-shaped divider is fixed in front of the wheel at the end of the cutter; this not only prevents the standing crop from being damaged, but also tends to raise fallen

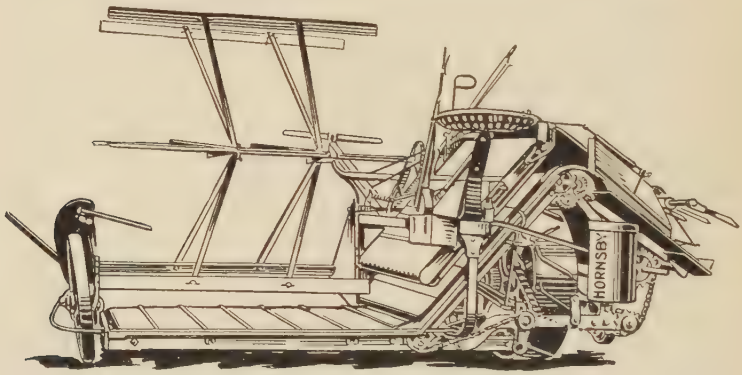


FIG. 28.—Hornsby Reaper and Binder.

shoots so that they are cut more readily. Another divider is placed at the elevator end of the cutter, but it only comes into action when the machine is "filled" to the utmost. A tilting lever is provided to regulate the height of the cutter bar.

The reel, which is caused to rotate by means of gearing, is adjusted by hand-levers, both vertically and horizontally, and can therefore be placed in whatever position is best suited to the length of the crop and the direction in which it may be leaning. Its action is to bend the straw slightly towards the knife so that it falls naturally on the platform as soon as it is cut.

As soon as the corn falls on the platform it is received by the bottom canvas and carried towards the two elevating

canvases, which raise the material to the deck of the machine. The canvases are all adjustable, and should be kept just tight enough to prevent slipping at the driving-pulleys. Special looseners are usually fitted, which enable the canvases to be slackened in a few seconds when the machine is being left overnight.

As soon as the corn reaches the deck it is acted upon by the packers and butters, which jointly compact the material into a sheaf and carry it to the knotter. The sheaf is compacted against a vertical lever which, when a sufficient weight of material has gathered, gives way and engages the binding gear. A curved and threaded needle-arm carries the twine round the sheaf and leaves it in the grasp of the knotter, which ties and cuts the twine; the sheaf is then kicked off the deck by a set of three levers.

The principal adjustments which may be carried out on the deck are those which regulate the size of the sheaf and the position of the band. To regulate the distance of the band from the butt of the sheaf, a lever is employed which alters the position of the whole of the deck and the knotting mechanism relatively to the elevating canvases and the butter, and it is thus possible to tie every sheaf in the centre no matter what the length of the straw may be. To regulate the size of the sheaf, the compression and trip levers have a range of adjustment, and the tightness of the twine can be controlled by varying the compression of the spring actuating the trip lever.

The difficulty of moving a binder from field to field, when it is in its working position, is overcome by providing each machine with removable wheels for travelling purposes. These wheels are fixed on the front and rear of the frame, the driving and grain wheels are elevated out of the way, the draw bar is shifted into a position at the extremity of the platform, and the machine is ready for transportation through gates, along roads, etc.

Care of Mowers and Reapers.—For long life and satisfactory working it is of the utmost importance that

careful attention should be paid to the lubrication of the moving parts. Makers cannot supply their machines with oil feeds and numerous grease cups at a competitive price, and it is essential that the farmer should use his oil-can regularly and frequently, in order to avoid excessive draft on the horses and rapid wear of the parts. Good, heavy-bodied oil should be used; waste oil drained from a tractor sump is infinitely preferable to many of the cheap paraffin-like oils offered to farmers.

For clean cutting and light draft the knives should be removed and sharpened at least twice a day when the machines are in use, and more frequently on stony land. The best plan is to keep a few spare knives, and where two or three machines are working on one farm a man can be kept fully employed sharpening knives and attending to oiling and breakdowns.

Canvases should be slackened off after each day's work, and the machines covered over to protect the parts from rain and dew.

When the season's work is over, the machines should be thoroughly cleaned, overhauled, and worn parts renewed; greasy oil-holes should be washed out with paraffin, and all bearings should be left oiled. Parts that are liable to rust may be painted over with a mixture of paraffin and thick oil: the paraffin carries the oil into all the interstices of the mechanism, and when it evaporates leaves the parts coated with a thin protective film. The canvases should be removed and if necessary sent to the saddler to have all rents repaired, broken slats renewed, etc., and afterwards stored in a dry place.

With regard to the problem which presents itself to the farmer as to which make of machine he should buy, there is, in fact, little to choose between modern implements turned out by reputable makers. A good plan is to purchase from a local agent who carries a full stock of spare parts. The availability of spare parts is of the utmost importance in the case of a breakdown as delay may bring the harvesting operations to a standstill. Where several machines are

bought they should be of the same make so that their parts are interchangeable, and the farmer can afford to keep a few useful spares himself.

Haymaking Machinery.

The process of haymaking and the use of haymaking implements are considered in detail in Book II.; in this section it is only possible to give a brief description of a few of the haymaking machines in common use.

The Horse-Rake.—The horse-rake is not only used for dragging hay into windrows and raking over hayfields, but is employed for raking stubbles after the principal harvesting operations have been completed. The construction of the rake is simple and can be clearly seen in Fig. 29. In the older types of machines the teeth were raised by means of a tilting lever when it became desirable to deposit the load; but in most new makes a self-lifting mechanism is incorporated, which, by means of a friction or pawl clutch brought into action by the pressure of a pedal, causes the wheels to raise the teeth and by this means frees the implement of its load. Side-delivery rakes may be used for gathering the crop into windrows, but these are generally combination implements with a number of different actions.

The Swath Turner.—The swath turner is employed to turn over the herbage which has been left on the ground by the mower, so that it receives further exposure to the drying action of air and sun; it does not ted the material in any way, and causes a minimum of damage to the brittle tissues. The principle of the swath turner, which is generally constructed to deal with two rows, is to employ rotary forks which roll the hay into an inverted position as the machine is advanced. Fig. 30 illustrates a combination machine, which, by the introduction of extra rake sections, can be converted into a side-delivery rake for the formation of windrows parallel to the line of draft. Other machines have independent forward and reverse gears to each set of rakes: they can turn the swaths to the right or left, or together so that they form small windrows.

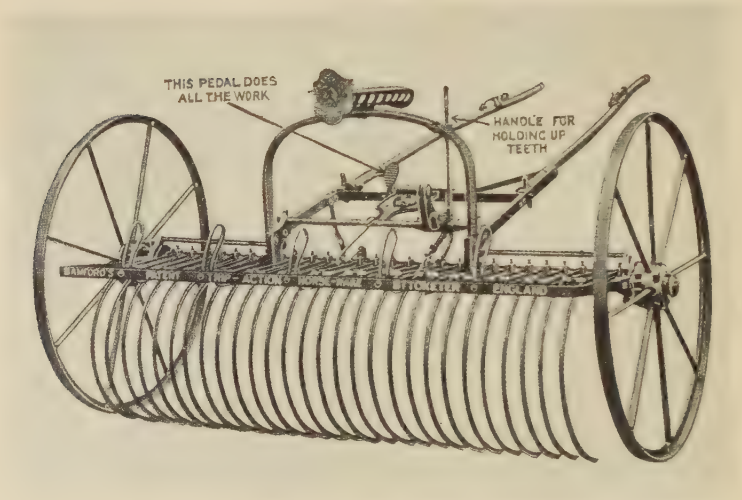


FIG. 29.—Self-acting Horse Rake. (*Bamford.*)

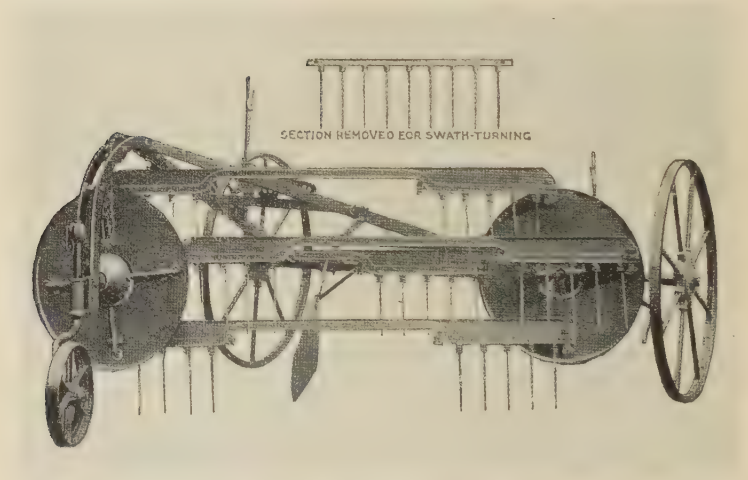


FIG. 30.—Combination Switch Turner and Side-delivery Rake. (*Bamford.*)

The Tedder.—Fig. 31 illustrates a rotary tedder, which is used to ted and scatter the hay over the surface of the field, thus facilitating drying. For very thorough work the

FIG. 31.—Hay Tedder. (*Bamford.*)

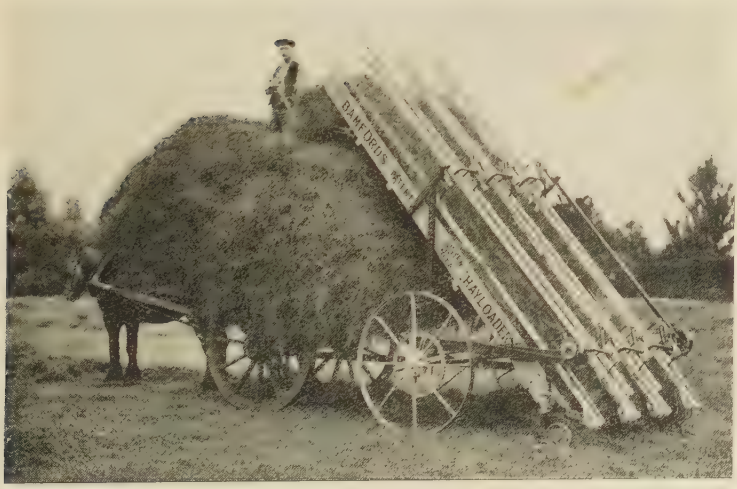


FIG. 32.—Hay Loader attached to Cart. (*Bamford.*)

machine can be given a forward motion which carries the hay up under the guard and throws it backwards over the axle. For less drastic treatment the motion of the forks is reversed, and the material is tedded backwards without

raising it from the ground. Some makes of tedders have a kicking action, and spread the hay by means of their oscillating forks. All tedders tend to damage the herbage considerably and leave it uniformly spread over the ground —a condition that renders it easily damaged by rain.

The Hay Loader.—The hay loader (Fig. 32) is a wheeled elevating gear, made either on a fork or an endless apron principle, which is attached behind the hay wagon. The drive for the mechanism is taken from the wheels, and when the wagon is moved forward the hay is raked up, carried to the top of the elevator, and dropped on the wagon where it is trampled and built by a man in the usual way.

Hay Sweeps.—Hay sweeps are really transporting rakes, with long horizontal wooden tines; they are used for collecting hay that is in windrows or cocks and for dragging it to where the stack is being built. These implements save an immense amount of labour, but as they cannot be taken through gates or along roads they can only be used where the stacks are constructed in the field. A gang with two men on the stack and one at the elevator can, by the aid of a large two-horse wheeled sweep, handle as much as 20 tons of hay in a day. Some of the smaller forms of "hay-drags" and "tumblers" require one horse only and can be tilted to dump their loads; but a full-sized sweep has to be dragged out from beneath its load by backing the horses.

The Stack Elevator.—Stackers are constructed in the form of a sloping wooden gangway in the bottom of which are endless chains with upstanding teeth, which, when the gear is in motion, carry the hay from the ground to the top of the stack. Elevators are telescopic, adjustable for height, and are usually worked by means of a horse gear or a small oil-engine.

The Horse-Fork.—This is a form of crane used to raise hay from the ground or wagon to the stack. Special forks are required for seizing the hay, and these may be either in the form of a double harpoon or a four-tined grapple, which works on the principle of ice-tongs. The fork works best when the hay is brought to the stack in wagons and is well

consolidated. When the horse, which is used instead of a windlass, has raised the material over the eaves of the stack, the grapple is released by the jerk of a cord and the load is deposited.

Machines for the Potato Crop.

Potato Digger.—Fig. 33 illustrates a modern potato digger—a type of machine used on every potato-growing farm—which, although its draft is not much greater, produces more satisfactory work than a potato plough. The machine is provided with a very strong share which is dragged

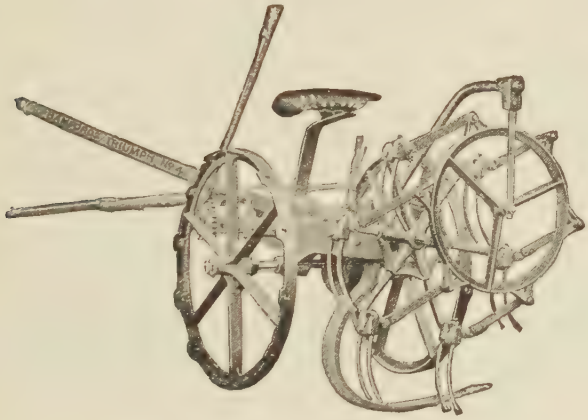


FIG. 33.—Potato Digger. (*Bamford.*)

under the potato drill, and completely loosens the soil and the tubers. The share is followed by revolving digging-forks, kept in a vertical position by means of a link-motion system, which throw the whole of the soil and crop at right angles across the track and leave the potatoes on the surface. An adjustable screen (not shown in the illustration) is often fitted to facilitate gathering by preventing the tubers from being thrown too far.

The mechanism of the machine consists of simple gearing to transmit the power from the wheels to the revolving parts, and the necessary clutch to put the machinery in and out of action. A tilting lever is provided to put the share in and

out of the ground, and to vary its depth according to the requirement of the crop. Another adjustment, rendered necessary by certain soil conditions, effects the alteration of the angle of the digging-forks by moving the socket carrying the link gear.

It is seldom that a potato digger works unsatisfactorily, but if the potato tops are heavy and green it may be necessary to scythe them down and remove them to prevent persistent clogging of the share. Again, when the share is worn, it may be difficult to get the machine to work to its full depth, and many of the tubers may be sliced or left buried. This trouble is most common in dry seasons when the land is hard. The remedy is, of course, to have a new point fitted to the share.

Potato Planter.—Many types of machines have been devised for potato planting. Some have been very elaborate, and aimed not only at setting the tubers but also at forming and splitting the drills in one operation. Others have been so simple that they were little more than light-wheeled frameworks from which the sets were dropped down spouts by the operators.

Fig. 34 represents a double-row Richmond planter, which serves to illustrate the principles of the dredge type of machine. Although there are single-row planters it is more usual to employ two-row machines, which can be drawn by a single horse; and sometimes a hopper and distributing gear are fitted to combine the spreading of artificial fertilisers with the work of setting. In the Richmond machine the sets are picked up from the hopper by buckets attached to an endless chain, elevated to the top of the machine, and tilted into tubes by which they are delivered into the drills at regular intervals. The distance between the sets can be varied to meet the requirements of the farmer by the introduction of sprocket wheels of different sizes, which vary the speed of the elevating gear. The buckets are designed to prevent doubles from being carried, and this is further ensured by the angle of the elevating chain which is adjusted by a tilting lever so that any extra sets roll out of the cups

back to the hopper. A "kicker" is provided to clear the cup at the right moment in case the set is jammed.

To get the best results from the machine the seed should be of the right size; it should be dressed through a $1\frac{3}{4}$ or $1\frac{5}{8}$-in. riddle, the smaller mesh being used for tubers that are long in shape. Fair results can be got from cut seed if the surfaces have been dried to prevent sticking and the sets are not too large. In order to prevent doubles

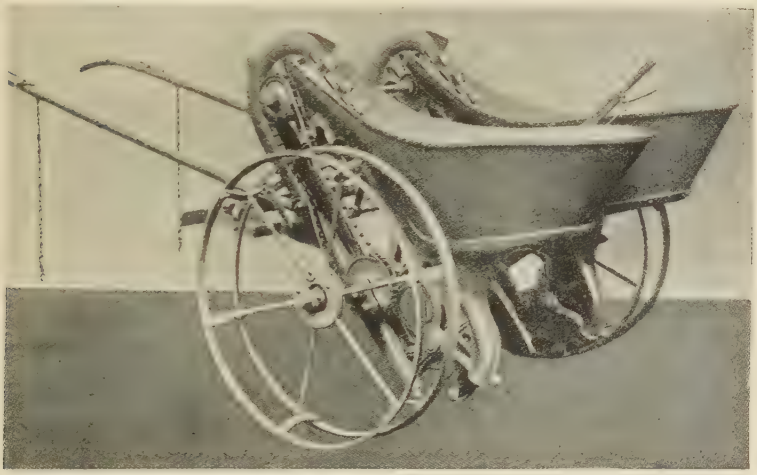


FIG. 34.—Double-row Potato Planter. (*Wallace.*)

from being carried in the buckets, it is important that the machine should be kept tilted as far forward as possible, provided that no single potatoes fall out of the cups. When the proper angle has been obtained, the machine should be kept at that angle by using the tilting lever on inclines and declines. A few blanks and doubles may result, but these are easily rectified if a lad is set to follow the planter.

Potato Sorter.—Before the introduction of the mechanical sorter potatoes were invariably separated into various sizes by passing them over hand riddles, which are still used to some extent in conjunction with light iron frames.

A modern sorter, such as that illustrated in Fig. 35, separates the material into ware, seed, chats, and dirt by passing it over oscillating grids and riddles. The two main riddles are removable, and are supplied in many different sizes. The most common mesh for a top riddle, which removes the ware from the rest, is from $1\frac{5}{8}$ to 2 in., and that of the bottom riddle, which removes the seed from the chats and dirt, $1\frac{1}{4}$ in. A conveyer is provided which carries the ware to the bagging apparatus. This allows one or two operators to pick the tubers over and remove all that are malformed or affected by disease. The power

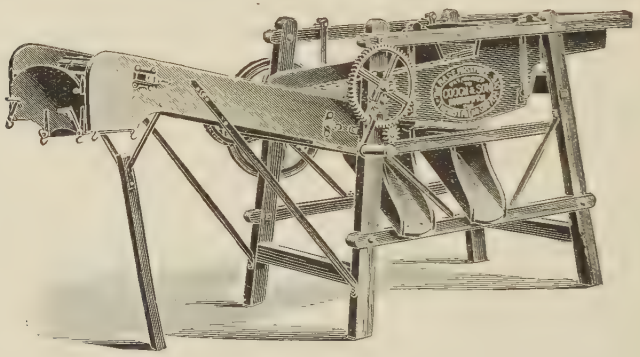


FIG. 35.—Potato Sorter. (*Cooch.*)

is transmitted from the hand crank to the oscillating riddles and conveyer by means of a chain and countershaft; but many of the larger machines are now turned out in conjunction with a small internal combustion engine, the complete assembly being mounted on wheels to facilitate transportation. The machine should be as low as possible so that filling is easy, and it must be easily portable as it has to be moved very frequently in the course of a day's work. The amount of material that can be dressed in a day depends very much on the presence or absence of disease and sprouts, and may be from 3 to 12 tons.

Threshing.

Threshing is the process of removing grain from its straw and chaff, freeing it from impurities, and fitting it for the market. Machines designed for threshing vary greatly in size and capacity for work. As a rule, the output of a machine is proportional to the size of its drum, which may be from 2 ft. to 5 ft. 6 in. wide. The ordinary English portable thresher has a 4 ft. 6 in. drum, 22 in. in diameter, which revolves at a speed of about 1000 revolutions per minute, and is capable of threshing a maximum of 36 cwt. of wheat or oats, or 40 cwt. of barley per hour. Such a machine has to be driven by an engine capable of developing about twenty brake horse-power. Fig. 36 illustrates the working parts of a Ruston thresher.

The Operations of Threshing.—The corn is fed into the top of the machine by hand after the sheaf bands have been cut, or is placed on a mechanical feeder. The self-feeder (not illustrated) is usually constructed in the form of an endless travelling canvas carrier, which is fitted with a device for shaking out the sheaves by tedding and oscillation, and may or may not be fitted with a band cutter. The object of self-feeders is, of course, to economise labour, and most makers fit them as extras. When the corn enters the machine it falls between the revolving drum and the concave, and the grain is knocked out of the ears. The straw passes on to the shakers, where the grain and chaff are thoroughly shaken out, and is passed out at the end of the machine; it may be allowed to fall on the ground, or it may be received by an elevator and transported to the stack, or a trusser may be fitted which automatically ties the straw into bunches with either single or double strings.

Everything that descends through the concave and shakers falls on the collecting-board or top shoe, which by its oscillation carries the material back to the middle of the machine and allows it to fall on the caving riddle. The oscillation of this riddle carries the cavings forward and

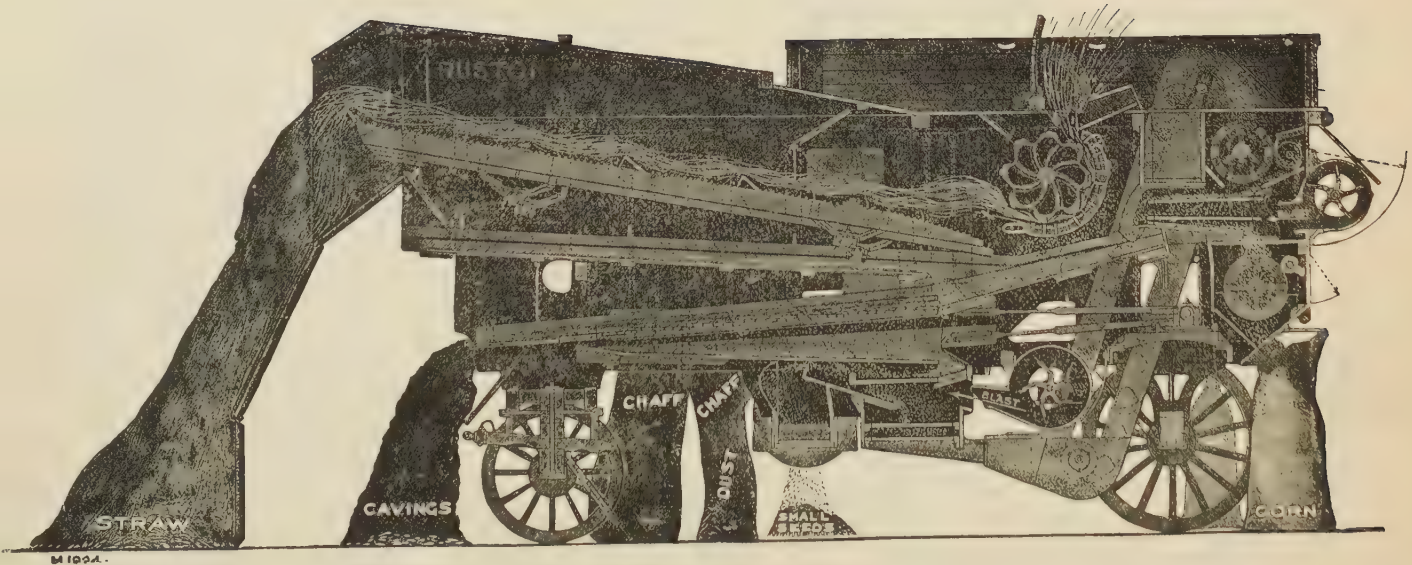


FIG. 36.—Side Sectional View of Modern Thresher. (*Ruston.*)

delivers them on the ground below the straw board, but the chaff, grain, etc., fall through to the bottom shoe or collecting-board, and are again carried to the middle of the machine where they fall through an opening on to the wind riddle which receives a strong blast of air from the large blower. This blast removes the chaff from the grain and weed seeds, and either delivers it on the ground or passes it into bags through a special bagging apparatus.

The winnowed grain passes into the first dressing apparatus, which is designed to remove weed seeds, stones, etc., and then down an oscillating spout into the endless belt and cup grain elevator. The grain may be delivered from the elevator:—

(1) Through the awner and smutter, which removes beards and polishes the grain, into the second set of dressing riddles, where it is subjected to a blast of air from the small blower and freed from dust, awns, etc., and then into the rotary screen, which sorts the grain according to size and delivers it into sacks.

(2) Through a creeper or worm which carries the grain to the second dressing apparatus without passing it through the awner and smutter, and hence through the rotary screen into bags.

(3) Through the creeper and second dressing apparatus into bags without going through the rotary screen.

(4) Directly into bags.

The Practice of Threshing.—The thresher is provided with two spirit levels, and, if the work is to be satisfactory, must be placed absolutely level before operations commence. The transmission of power from the engine is by belt, and the driving and driven pulleys must be perfectly aligned if the belt is to be prevented from jumping off. The belt must not be too tight or it will throw undue strain on the bearings, which may heat. All bearings must be kept thoroughly oiled and cleaned; oil is cheaper than new bearings, and if oiling is neglected costly repairs will be inevitable. The machine should be gone over after every day's work, and all nuts should be kept properly tight. Should a knock or

grinding noise develop during threshing the machine must be stopped at once and the fault remedied, otherwise a serious break-down may occur. Feeding must be regularly and carefully performed: a choked drum resulting from over-feeding throws an enormous strain upon the mechanism and may cause a breakage.

The sample of grain must be examined from time to time to ascertain its condition; the straw should be examined for thoroughness of threshing, and the chaff for the presence of grain. Whenever imperfect work is being done the cause should be ascertained and the fault remedied immediately.

When certain parts of the machine are not in use, for example the smutter or rotary screen, their driving-belts should be removed to reduce wear and save engine-power.

Adjusting the Concave.—The revolving drum beats the grain out of the ear by striking it against the concave, and it is of the utmost importance that the concave should be adjusted to suit the class of cereal that is being threshed. If the setting is too wide the straw will pass out of the machine imperfectly freed from grain, while, on the other hand, too close setting produces violent concussion, and a proportion of the grain may be broken or badly bruised, and much of the straw may be broken up into cavings. The ordinary distance between the drum and the concave for threshing cereals is 1 in. at the top, $\frac{1}{2}$ in. at the middle, and $\frac{1}{4}$ in. at the bottom. A closer setting is generally necessary for damp grain because it is difficult to remove from the straw, but when the corn is dry and brittle a wider setting will give satisfactory results. The adjusting screws for the concave are shown in Fig. 37. It is important that the same number of turns should be given to the nuts on each side of the machine, and adjustment should never take place while the thresher is in motion.

Drums that have been in use for a considerable time become worn in the centre, where most of the corn is usually dropped, and when they are adjusted to give good results in the middle tend to crack the grains which fall towards the sides. Drums in this condition should have their bars

renewed or straightened, and the concave must be given similar attention.

Regulating the Blowers.—The strength of the blast can be regulated by opening and closing the blower slides. When cleaning out the machine the blasts should be fully opened and the thresher run at full speed, empty, to clear the riddles, etc. The weight of the grain determines the strength of blast required, and adjustment should be made so that all the chaff is blown away and yet no light grain is carried with it.

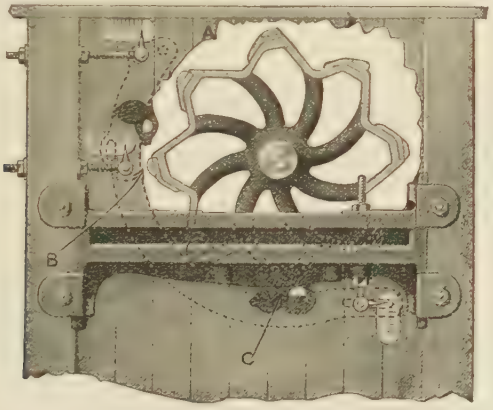


FIG. 37.—Adjustment Screws of Concave. (*Ruston.*)

Selection of Riddles.—The object of the riddles is to remove pods, seeds, dirt, etc., from the grain, and it is important that suitable riddles should be fixed in the dressing shoes for the particular kind and quality of corn to be threshed. Large grains like oats require larger riddles than wheat, and wheat than rape. When the grain is a little damp larger riddles may be necessary. In all cases the smallest riddle that will remove the refuse and yet allow the grain to pass should be used.

As a rule, the following are the sizes of riddles used in English threshing machines:—

The first dressing apparatus, consisting of an upper,

permanent Capes riddle and a lower, first dressing riddle, which is changed to suit the crop,

First Dressing Riddle.

Clover, rape, and linseed	3/16 in. mesh
Rye and small wheat	7/32 „ „
Medium wheat	1/4 „ „
Large wheat and small barley	5/16 „ „
Large barley	3/8 „ „
Oats, beans, and peas	1/2 „ „

The second dressing apparatus, consisting of two riddles, both of which must be changed to suit different types of corn,

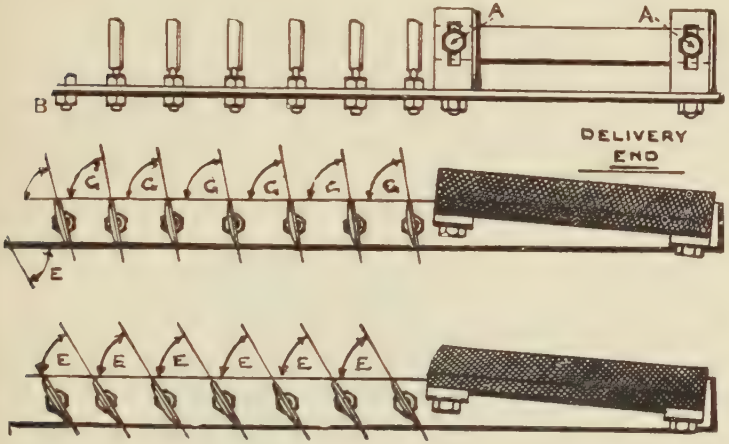
	Upper Riddle.	Lower Riddle.
Wheat	5/16 in. mesh	1/4 in. mesh
Barley	3/8 „ „	5/16 „ „
Oats	5/8 „ „	1/2 „ „
Rye	5/16 „ „	1/4 „ „
Beans	5/8 „ „	not used
Peas	1/2 „ „	„
Clover and linseed	1/4 „ „	1/4 in. mesh

A complete set of riddles is sent out by the makers with each machine, and each is marked according to the work for which it is suited.

The Rotary Screen.—The rotary screen separates the grain into "firsts," "seconds," and sometimes "thirds," and then delivers it to the bagging apparatus. The screen can be adjusted to suit different kinds of grain by fixing a handle to the end of the shaft and turning; the mesh is increased by screwing to the right and reduced by turning to the left.

The Awner or Smutter.—The smutter consists of a rotating shaft carrying a number of knives and bars which move in an iron cylinder or wire cage (Figs. 38 and 39). The grain enters at the knife end and is gradually worked through the cylinder owing to the "set" given to the blades, which cut the awns off barley; it next reaches the bars, which further free it from awns and dust, polish it, and deliver it into the second dressing apparatus.

The set given to the blades determines the time the grain takes to pass through the smutter, and if thorough treat-



A. Adjusting nuts for bar. B. Adjusting nuts of knife. G. Set for slow passage of grain. E. Set for quick passage of grain.

FIG. 38.—Diagram showing Smutter Knives and Bars. (*Ruston.*)

ment is required, the angle is adjusted so that the grain is subjected to the process for a longer period. The average distance of the knives and bars from the casing is $\frac{3}{8}$ in.,

FIG. 39.—Smutter Case lined with iron and wire. (*Ruston.*)

but is adjustable (Fig. 38); it is decreased for small grain, and increased for large.

When broken grain is being delivered the cause may be either in the drum or the smutter. To ascertain which requires adjustment, examine the grain as it leaves the

elevator, *i.e.*, before it reaches the smutter. If it is cracked at this point it is obviously the result of too close a setting of the concave.

Threshing Wheat.—When the proper riddles have been inserted, wheat may be passed through the whole of the cleaning and sorting apparatus, but it need only be put through the rotary screen when it is desirable to sort it into different grades. Bunted wheat must not be put through the smutter, which breaks up the bunted grains, liberating the spores, and so spoiling the whole of the sample. If in a wet or soft condition wheat may be bruised in the smutter, and should be passed through the creeper.

Threshing Oats—The proper riddles, which are larger than those required for wheat, should be fixed. Oats should always be passed through the creeper, as the action of the smutter is liable to break and shell the grain. Sometimes oats do not require a second dressing and may be sacked direct from the elevator.

Threshing Barley.—It is particularly desirable that barley should not be "nibbled" or broken in threshing, because its value for malting purposes would thereby be greatly reduced. The sample must be carefully examined from time to time, and the concave and smutter adjusted at once if broken grains are being delivered. The feeding must be very regular and should not be hurried.

Threshing Beans and Peas.—The concussion of the ordinary drum is too great for beans and peas and causes a large proportion of the sample to be broken, and for this reason most makers furnish special drums for pulse threshing. For moderate quantities, however, the drum may be made suitable by the removal of every second beater, or a larger pulley may be fitted which causes the drum to revolve at a lesser speed. The upper portion of the concave should be thrown right back and fitted with an iron plate—supplied as an extra by the makers—and the bottom portion should be lowered to $\frac{5}{8}$ in. from the beaters. Feeding should be done carefully and slowly. Beans and peas should not

be passed through the smutter, and cannot pass through the rotary screen; they may be delivered into sacks from the elevator.

Food Preparing Machines.

The Chaff Cutter.—Chaff cutters are made in almost all sizes, from small hand machines to large power cutters which are capable of dealing with material as fast as it can be forked. The chief working parts consist of a large flywheel, which has the steel cutting knives fixed to its

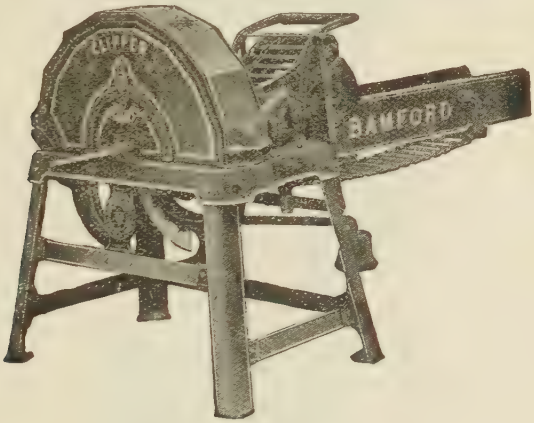


Fig. 40.—Power Chaff Cutter.

spokes, a self-feeding arrangement to carry the hay or straw to the knives, a change speed gear which allows the material to be cut into different lengths, and a clutch to put the mechanism in and out of gear. Cutters are frequently used in conjunction with threshing machines receiving the straw from the shakers, cutting it, and delivering it into bags. Large-sized chaffers are usually fitted with an apparatus which frees the material from dust. A medium-sized, self-feeding chaff cutter is illustrated in Fig. 40.

The Corn Grinder.—Grinding mills should be capable of producing any degree of fineness, from broken beans to cereal flour. In a modern machine the process begins by passing

the material through the "cracking cones," which produce fragments that are easily ground between the revolving grinding plates. These plates are held together by the pressure of a spring, the compression of which can be varied, according to the fineness of the meal required, by the adjustment of a screw. Should a piece of stone or metal get into the machine the spring will yield and prevent the plates from being scored or damaged. A roller mill does

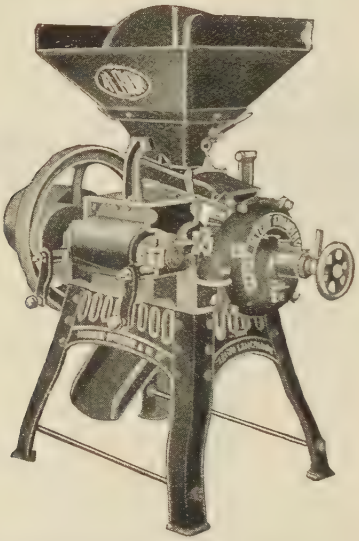


FIG. 41.—Combined Grinding and Crushing Mill. (*Harrison, M'Gregor.*)

not grind the material but simply rolls it out flat, and is most largely used in the production of crushed oats for feeding purposes. Fig. 41 illustrates a power machine that can be used for either grinding or crushing.

Root Cleaners and Cutters.—A root cleaner is designed to remove the adhering earth from mangels, turnips, etc., and is usually built in the form of a revolving sparred drum. As the roots pass through this drum they are agitated and scraped and the dirt falls through the spars to the ground below. The drum can be elevated or depressed at one end

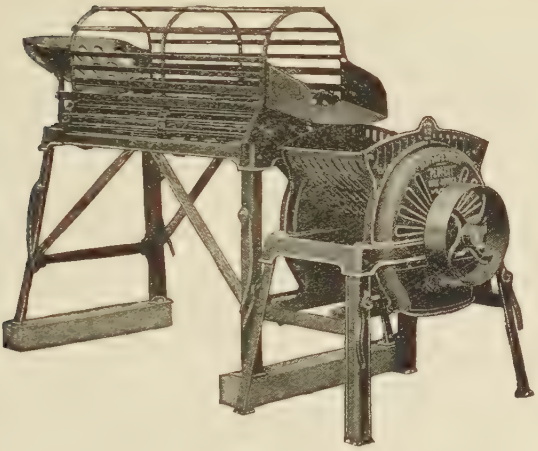


FIG. 42.—Root Cleaner and Cutter. (*Bamford.*)

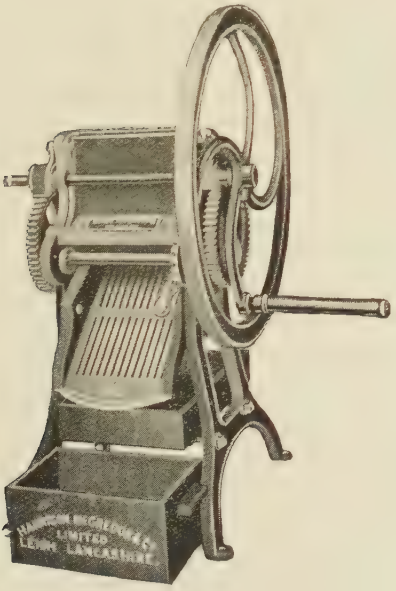


FIG. 43.—Oilcake Breaker.

by means of a screw, and consequently the speed with which the roots pass through and the thoroughness of their treatment can be varied according to their condition. Cutters are made in several different forms, and may either slice the roots or cut them into fingers of various lengths, the work being performed by slicer knives or finger-piece cutting discs. (See Fig. 42.) Turnip-cutters may be fitted to carts, and can be used for automatically cutting and distributing roots on grassland.

Cake Breakers.—When oilcake is received on the farm it is usually in the form of long flat cakes, which must be broken up before being fed to stock ; the size of the fragments has to be varied for different kinds of animals. The old method of breaking cake with a hammer is too laborious when a large head of stock is kept, and a simple cake-breaking machine soon pays for its cost in its economy of time. The essential parts of a breaker are a framework, two toothed rollers connected up to the driving apparatus by suitable gearing, and an adjusting arrangement whereby the rollers can be set to produce material of any desired degree of fineness. Fig. 43 illustrates a simple hand breaker suitable for most requirements.

BOOK II

CROPS

CHAPTER I

THE CEREALS—WHEAT

THE cultivation of wheat was begun in prehistoric times and the cereal was greatly valued by the ancient Persians, Greeks, and Egyptians. The varieties which are now grown in almost every country throughout the world appear to have been evolved through selection, mutation, and hybridisation from two or three wild species.

Wheat, since it is the favourite cereal for the production of bread, is the most important of the corn crops. Each grain of wheat consists of an embryo plant in close contact with an ample store of starchy and nitrogenous food material, the whole being surrounded by a pericarp or coat, which goes to form the miller's bran. Flour consists of the most digestible portion of the food store, and is obtained by subjecting the grains to a milling process. The admirable qualities of wheaten flour depend largely upon the nature of the nitrogenous portion, which is in the form of gluten. When the flour is prepared for the baking process, some of the starch is converted into sugar, which in turn is broken up by the action of the yeast, with the formation of carbon dioxide gas, whereby the dough is puffed up into a spongy mass. The so-called "strong" wheats have a high gluten content, and the dough produced is of a tough, rubbery nature that prevents the escape of gas and produces a light, well-risen, even-textured loaf. Wheats grown in certain warm, sunny countries are "strong" and produce good baking-flour, while British-grown wheats are on the whole

weak, and have to be blended with foreign wheats for bread-making. The diastatic power of wheat, *i.e.*, its capacity for producing sugar, is also important, and sometimes bakers have to blend malt extract with flour of poor diastatic quality.

Milling of Wheat.—Before milling takes place the wheats are blended, so that the flour produced will be of the desired strength for baking purposes. In modern flour-milling the wheat is first of all subjected to a very thorough cleaning process. Not only are the weed seeds and foreign matter that would injure the quality of the flour removed, but great care is taken to get rid of stones, pieces of iron, and scraps of material that would be likely to injure the delicate machinery used in the milling process. The milling proper is done by passing the grain between a series of rollers of increasing fineness and closeness of setting, so that the berries are cracked and the endosperm or floury portion is liberated with the least possible breaking up of the dark coloured bran. At each stage the material issuing from the rollers is sorted out, by means of sifting machines and fans, into materials of different grades and degrees of fineness. Normally only about 68 per cent. of the grain was recovered as flour, but during the War the extraction was raised to over 90 per cent., which resulted in a greater food value being obtained; the material, however, was inferior in digestibility. The final products of the milling process are: (1) Flours and semolinas of different grades; (2) wheat germs; (3) middlings or pollards; fine sharps or seconds, and coarse sharps or thirds; (4) coarse, medium, and fine brans.

Quality of Wheat.—Wheat is valued according to its suitability for milling purposes. A good milling wheat should yield the largest possible proportion of flour and a correspondingly small proportion of milling offals; this quality is indicated by the thinness of the bran and the largeness of the wheat grains, large grains having a relatively smaller surface than small grains, and consequently a smaller proportion of bran. It is essential that the wheat should be in a sound condition, free from odours and indications

of heating; it should also contain a minimum of weed and other foreign seeds. The wheat should be hard, as hardness indicates the presence of a minimum proportion of water.

A strong wheat is indicated by a hard flinty appearance and absence of flouriness when the grain is broken with a hammer or examined in cross section. On the other hand a typical weak wheat has opaque grains which when broken reveal a smooth white floury endosperm. By the liberal use of nitrogenous manure or by early cutting of the crop it is possible to give the grain of a weak wheat a translucent appearance, but such grain when broken yields a soft flour. A shrewd idea of the strength of a wheat can be had by chewing a few grains until the starch has disappeared and then examining the quantity and toughness of the gluten which remains behind.

If wheat is being bought for seed purposes it should be plump, with a smooth, well-filled skin, and show every indication of having attained perfect maturity at harvesting; it should bear no signs of weathering in the field or heating in the stack, and it should be as free as possible from weed seeds, a condition of much greater importance than when the wheat is to be used for milling. By far the best measure of seed value is, however, the result of a well-conducted germination test.

The best wheat from the farmer's point of view is not necessarily that which will bring him the highest price per quarter from his corn merchant. In growing his wheat he must aim at a maximum profit per acre, and this may only be attainable by growing a wheat of slightly inferior quality that is a heavy yielder. He should aim at a maximum yield of grain and straw, provided that the quality is not so inferior that a poorer yield of better milling value would give a greater monetary return. To attain this end he must select varieties which are suited to the soil and climate of his district; varieties resistant to the diseases that may infest his farm; and, should his land be in good heart and capable of producing a maximum crop, varieties which have

sufficient strength or shortness of straw to prevent the lodging of the crop.

Varieties of Wheat.—Wheat, in common with many other gramineous plants, is practically always self fertilised. Under ordinary conditions each sort breeds perfectly true, and selections from individual plants of outstanding merit will lead to disappointment as the crop raised from the selected ears will go back to the old standard. How, then, have the dozens of varieties of wheat come into existence? Some, no doubt, have been developed from rare cases of cross fertilisation under natural conditions. The great majority of our wheats, however, have been produced by artificial cross fertilisation of pre-existing distinct varieties. The exchange of germ-plasm brought about in this way leads to the evolution of new varieties, some good and some bad, and from these varieties, after a long and laborious process of selection, improved wheats are continually finding their way into general cultivation. Wheats that give the best results under one set of conditions do not necessarily prove superior when grown in a different environment of soil and climate. The best cropper on an Essex clay may give a poor yield when grown on one of the silts of the Midlands.

The following are a few of the varieties of wheat in common cultivation at the present time:—

Square Head's Master and Standard Red.—These are very similar red-chaffed wheats, probably obtained by selection from the same source. The ears are long and rather open; the straw is long, stiff, and stands up well. The grain is of good average quality for a British wheat and the yield is very good. The varieties are extremely adaptable to a wide range of soil and climatic conditions, and may be grown in the less favourable wheat districts. These wheats are rather susceptible to rust attacks, but they are not the worst in this respect.

Little Joss.—A red wheat with red chaff, produced at Cambridge University by crossing Square Head's Master with the Russian wheat Ghirka. Through its parentage it has a remarkable power of resistance to yellow rust, and it

gives superior yields in districts where this disease is common. It resembles Square Head's Master except that it has a less compact ear and the straw is longer and weaker. In the few districts of East Anglia, where the incidence of rust is severe, the variety is extremely popular, and although it may not be so strong in the straw as is desirable it has the remarkable property of ripening quite well after it has lodged. It is one of the very best wheats for cultivation on really light soil.

Swedish Iron.—A variety sent out by the Svalof Plant Breeding Station in Sweden. It produces large yields of grain and the straw is very stiff; hence it stands up better than most other varieties. It is advisable to sow about half a bushel more seed to the acre than of the common English sorts, as the grain is large and the plants do not tiller well. In the northern and the cooler parts of the country Iron has given the largest yield in many variety trials, but it does not do so well on light soil. In winter it is backward, and it may look very disappointing before the active spring growth sets in. The quality of the grain is distinctly below average; indeed the wheat is better used for poultry feeding than for milling. The variety is markedly resistant to yellow rust.

Victor.—An introduction of Messrs Garton, Ltd., which appears to be very similar to the Dutch wheat Wilhelmina. It possesses a very compact square ear, with greyish chaff and white grain. It is a heavy cropper especially on strong and rich soils; its straw stands well. The soft white grain is distinctly inferior to Standard Red for bread-making. The variety is liable to attacks of yellow rust and mildew and shows a tendency to sprout in the stook during bad weather.

Yeoman.—A variety produced by Professor Biffen by crossing Red Fife, a very strong wheat, with Browick. The ear is square and moderately long, the grain is red and the chaff white. The straw is short and strong, making the variety suitable for rich land. The yield is generally as good as that of Standard Red and the variety is resistant to yellow rust. The outstanding feature of Yeoman is its strength and

it gives a flour that does not have to be blended in order to fit it for bread-making. A crop of Yeoman generally produces better results on threshing than one might expect from its appearance during growth. The variety responds well to liberal treatment.

Yeoman II is a selection from the same cross which produced Yeoman. It resembles Yeoman in practically all respects except that its grain possesses even greater strength.

Rivet.—A red winter wheat, specifically different from other British-grown wheats, that has an outstanding cropping capacity but is very late in coming to maturity. It produces a very long straw which stands well owing to its pliability rather than its rigidness; it is resistant to yellow rust but is liable to be attacked by mildew. Its bearded character makes it unattractive to birds and it is useful for growing where sparrows are destructive. The late ripening of the variety makes it useful for spreading out harvest operations. It is one of our best wheats for the heaviest classes of clay soil. The quality of rivet is so bad as to render it quite unsuitable as a bread wheat, but it is nevertheless preferred for certain classes of biscuits.

Red Marvel (Japhet).—A variety of spring wheat, originated in France. The straw is long and slender, and although the yield is heavy the grain is coarse and weak. It is extremely early in coming to maturity. It is liable to yellow rust and mildew.

For a botanical classification of the different varieties of wheat the reader is referred to works on Agricultural Botany.

The Cultivation of Wheat.

Soil and Climate.—Wheat thrives in subtropical, warm temperate, and cool temperate regions. It is grown in this country as far north as Morayshire, and is cultivated more or less extensively in all the eastern and midland counties. The western counties and districts of heavy rainfall are less suitable for wheat, because the crop requires a

large amount of sunshine for ripening. Wheat is extremely deep rooted and drought resisting, and gives the best yields in dry seasons; it is also more resistant to winter frost than either barley or oats. In Britain it is nearly always sown in autumn, so that advantage may be taken of the longer period of growth, which gives an increased yield and earlier ripening.

The more "body" there is in a soil the more suitable it is for the growth of wheat, consequently this cereal is found attaining perfection on heavy loams and clays. Satisfactory crops can be grown on light land in good condition, but if the land is light and also poor, wheat is likely to be a failure. Crops of wheat grown on light land are lacking in bulk, but the quality of the grain is not inferior; when grown on peaty soils the quality is usually poor, while the vegetation is luxuriant and the yield of straw very large. It is the safest cereal to grow on really rich land, as it stands heavy manuring, and, if a strong strawed variety has been selected, is not very liable to lodge.

Place in Rotation.—In districts where bare or bastard following is practised, wheat is almost invariably taken after the fallow. This practice allows very early sowing of the crop, although little wheat is now sown before September. During the fallowing operations, which are conducted at a time of the year when the temperature is high and the soil organisms are particularly active, the continual aeration, mixing, and stirring of the soil allows the organic matter to decompose rapidly with the ultimate production of nitrates. As the nitrates are not held in the soil but are carried away in the drainage water, it is advisable to sow a crop in the autumn which will be able to intercept and absorb these valuable manurial salts before they can be washed away by the winter rains. The wheat crop is admirably suited for this purpose. In most cases, also, the early sowing of wheat, as after a fallow, is an advantage, as it allows the plants to become so well established before the advent of winter that they suffer little from the ill-effects of frost and thaw.

Since bare fallowing is not very widely practised, the wheat crop frequently follows seeds, the decomposition of the turf providing a supply of useful manure. It may also, with advantage, follow potatoes, as then the soil contains a considerable residue of the heavy manuring usually applied to that crop. There is, however, no hard and fast rule, and wheat is frequently sown after leguminous crops, such as peas or beans, or after roots that have been carted or fed off early in the season.

Preparation and Sowing.—The quantity of seed required to sow an acre will vary according to a number of circumstances. Some varieties of wheat have much larger grains than other varieties, and if the same number of plants is required per acre in all cases, it is obvious that the large-grained varieties must be seeded at a heavier rate. If two or more wheats are to be tried together in a variety trial, it becomes necessary to make a count of a given weight of each variety. From the count the weights of seeding must be calculated, so that the same number of plants per acre will develop in each case.

The rate of seeding must also be varied according to the time of sowing. A field which, when sown in September at the rate of 2 bushels (9 stones) per acre, will produce a perfectly satisfactory crop, would, in all probability, produce an inferior crop if seeded at that rate in November, although a seeding at the rate of 3 bushels per acre at the latter date would give a normal yield. Early sown wheat, then, which has time to develop a strong growth in the latter end of the growing season, and will spread considerably before winter sets in, can be given a thinner seeding; if it is put in at a time when its spread is almost immediately checked by low temperatures, more seed must be used.

The optimum seeding depends too on climatic and on soil conditions. In the northern and upland districts more seed is required than in the more genial southern counties, almost twice as much being required at the one extreme as at the other. Good soil, because of its capability of producing active growth during the seedling stage, requires a

thinner seeding than poor, where the plants are incapable of doing more than existing during the winter months.

When seed is sown by broadcasting, a large proportion is too deeply buried and fails to germinate. If this method of sowing is practised, then it becomes necessary to apply the seed more liberally, about a bushel more being required to the acre than when it is put in with a drilling-machine. While the modern grain-drill is more economical than the old-fashioned sowing by hand, there is little doubt that there is still room for improvement in the distribution of the seeds over a larger surface, instead of packing them together so that they are in active competition in the bottom of a narrow drill. Such a distribution would, of course, prohibit the use of the horse-hoe; but this implement has largely gone out of fashion, and, moreover, the more even the distribution the more perfect is the smothering effect of the crop on the weed flora.

As a rule over-seeding results in a reduced yield of grain but an increased yield of straw; a seeding that is too thin to produce a full crop will generally give a high proportion of grain to straw. A thin seeding, however, has the disadvantage of allowing weeds to develop and spread.

If wheat is sown in spring it is usually done early in March or in February. Earlier seeding than this may be attempted, if the condition of the land permits, but it should be remembered that the ravages of rooks and other grain-devouring birds become particularly severe at a time of the year when food is scarce, and it is possible that these may remove most of the seed that is sown.

The method of preparing the seed-bed will depend on the preceding crop. If wheat is to be taken after a fallow, the last fallowing operations should be designed to leave a fairly firm bottom and a rough surface mould. If the land is ploughed, only a shallow furrow-slice should be turned over, and the use of the cultivator should then be sufficient to leave the soil in a fit condition for the corn-drill. The soil should on no account be worked fine, as overworking before

the winter rains may bring about the formation of a surface "cap" that prevents free aeration of the soil and is difficult to break up in spring.

When wheat is taken after potatoes, which leave the soil in an open, friable condition, a seed-bed can often be prepared by the use of cultivators and drags. If the land is ploughed, either after potatoes or after roots eaten off by sheep, a shallow ploughing will give the best results.

When the land is heavy, and the season too wet for the normal operations of tillage, wheat may be broadcast on the surface and ploughed in with a shallow furrow slice.

When wheat is grown after a crop of "seeds" the preparation of the ground is very simple, the grain either being broadcast on the ploughed land and harrowed in, or put in with a drilling machine after a rough tilth has been prepared by the use of harrows. If the crop is to be sown on freshly ploughed ley, a furrow press should be used to consolidate the seed bed.

Manuring of Wheat. — Wheat has a long period of growth and a deep rooting habit, and can usually be grown, if the land be in good condition, on the residues of previous crops and manuring. In most cases, however, with the possible exception of wheat taken after a strong leguminous crop, the application of 1 to 1½ cwt. of nitrate of soda in spring produces a marked improvement and a profitable return. A demand for nitrogen is frequently exhibited by a yellowing of the crop about the time when active spring growth is commencing. Under some systems of farming, where the proportion of grain to root crops is large, and where much dung is made during the winter months, the seeds land is top dressed with farmyard manure before it is ploughed for wheat, when no dressing of artificial fertilisers should be necessary. In some parts, soot, at the rate of about 4 cwt. per acre, is used in place of nitrate of soda as a spring dressing.

If wheat is taken after another corn crop, or after potatoes on land that is light and in poor heart, it may be necessary to apply 2 or 3 cwt. of a slow-acting nitrogenous

manure and 2 cwt. of superphosphate with the seed in autumn, followed by an active nitrogenous top dressing in spring. In some cases a remarkably poor crop of wheat is grown after a very good crop of potatoes, although, on the face of it, soil producing about 4 tons of dry matter per acre in a root crop should be capable of producing at least average wheat. The reason for such a failure is, of course, that the potato crop has thoroughly exhausted the soil, and the wheat suffers fromstarvation.

The long fibrous roots of the wheat plant pass through the soil and down into the subsoil to a depth measurable in feet, and in this way the natural resources of the soil, and the decomposition products of the original rock felspars, are well tapped; for this reason wheat seldom responds to the potassic fertilisers.

After-Cultivations.—In spring wheat is usually subjected to a fairly severe harrowing in order to break down clods, which readily fall to pieces after the winter frosts, and to tear up the surface "cap" that has been formed by the beating action of rain. The harrowing also drags out surface weeds, especially straggling weeds like speedwell, and has a beneficial action in separating the plants and causing them to tiller. Should the crop be thick it may be harrowed both ways, but if it be thin it is safer to harrow in the direction of the drills only; and, if the land be dirty with annual weeds, the harrowing may be repeated a number of times. The operation that follows the harrowing is usually a heavy rolling to consolidate the soil about the roots of the plants. On soil that is apt to dry out it is advisable to leave the surface loose. Cross rolling with a Cambridge roller is sometimes practised to check the ravages of wireworms. Horse-hoeing, which is of undoubted service in keeping the land clean, is still largely practised in districts where an absence of fallow crops allows weeds to accumulate. Hand-hoeing, a method of cleaning adopted for the suppression of strong-growing weeds, like thistles and docks (but far too costly to be applied to the surface annuals), may be practised until late in spring or until

the height of the crop renders it liable to serious damage. Charlock may be kept under by hand-pulling, but, if the land be very foul with it, the best treatment is to spray with a 4-per-cent. solution of copper sulphate. (See page 107.)

If the land is in good heart and the winter has been mild, wheat may become "winter proud," that is, it may be so much overgrown by the spring that it tends to become too heavy, and is likely to lodge before harvest. Wheat in this condition can be checked by turning on a flock of sheep and allowing the animals to graze it down fairly closely. It has been recommended that the sheep should be put on for a few hours daily, but it is questionable if there is any advantage in this practice, for if the crop really needs checking, it is certain to recover rapidly. Indeed, it has been shown that early sown wheat can be grazed down twice without injury to the final yield.

Harvesting.—If wheat is cut before its time the yield of grain is reduced, and much of the food material of the plant is retained in the straw; the sample is also poor in quality as the grains are shrunken and small, and particularly unsuitable for seed purposes. When a crop is cut too late the sample is bold, well filled, and of excellent appearance, but the bran is too thick to give the best yield of flour in the milling process; this condition, however, is ideal if the grain is to be used for sowing. The chief disadvantage of late cutting is the liability of the grain to shake out of the ear, both before and during harvesting operations. When wheat has assumed a distinct yellow tinge below the ear it is time to examine the ripeness of the grain with a view to reaping. The grains should be rubbed out of a few average ears, and their condition determined by pressing them between the thumb nails; they will probably be soft, but, should the crop be ready for cutting, they will exude no milky juice. If a milky fluid can be expressed from the seed the crop should be left for a few days, but when the grains have matured beyond this stage cutting should commence.

Before cutting with the reaper it is advisable to "open roads" round the field with a scythe, so that a way is made for the horses and the machine to move without destroying any of the crop. Nearly all the corn crops of the country are now cut with a combined reaper and binder, but this implement is completely satisfactory only if the crop is standing well. Should the wheat be leaning in one direction, so that the binder travelling in that direction simply pushes the straw further over, and either does not cut it or leaves too long a stubble, the binder should be used to cut one way—against the direction of lean—and then driven back to the starting-point with the mechanism out of gear. It may be possible to cut a crop with a reaping-machine or a mower when it will not cut successfully with the larger implement. A combined mower and reaper with a sheaf gatherer behind the knife, on which the crop falls as it is cut, and from which it is dropped by a foot lever when a sheaf has gathered, is a useful machine to use for cutting badly-laid corn; and in fact where there is only a limited acreage to reap it is a suitable implement for both hay and corn harvest. Eight binders are required to follow the machine when it is cutting one way. If the crop is badly laid in all directions it is necessary to cut it with the scythe or hook and bind it by hand; a good man and two binders are capable of clearing about an acre per day, which is a laborious business when it is considered that a mechanical reaper and binder can perform the same amount of work in an hour. Cutting with the binder should not take place if the crop is wet with rain or dew, as not only do the canvases tend to shrink and jam, but the excess of moisture in the tightly-bound sheaf causes undue delay in drying.

After the crop has been bound the sheaves are arranged so that they may dry as quickly as possible, and at the same time be able to withstand a spell of inclement weather. This is done by setting them up in shocks or stooks, each stook consisting of ten or twelve sheaves, half on one side and half on the other, arranged as far as possible in rows

running north and south so that each side obtains equal benefit from the sun. Pains should be taken to plant the sheaves firmly on the ground with the heads in close contact or the whole erection is likely to topple over in a slight wind, and much labour is required for re-setting. Daily re-setting of the stooks is essential during periods of mild and wet weather if the quality of the grain is to be preserved.

As a rule, the crop is ready for carrying in from four to fourteen days after cutting. This period is required for the proper drying of the straw, because, if too much sap is present when the crop is stacked, heating and moulding will ensue. In order to ascertain when the crop is ready to carry, a few straws should be taken from the middle of the sheaf and examined at the nodes. When these have become hard, shrunken, and concave in outline, it may be taken that the straw is sufficiently dry. When too much sap is present the nodes are soft, juicy, and convex. Care should be taken to examine the straw in all parts of the field, as a portion of the crop in a hollow or sheltered situation may still retain too much moisture when all the rest of the corn is fit to carry. If the farm, or particularly the stackyard, is situated in an enclosed position, the greatest care must be taken to ensure that the crop is in a thoroughly dry condition. If, on the other hand, the stackyard is placed on an elevated site, swept by winds from all quarters, the same care is hardly necessary, as the risk of heating is greatly reduced. When once the crop is dried, a shower of rain should not be allowed to hinder the carrying operations as the surface moisture will do no harm: in this respect wheat is more easily managed than the other cereals.

The method of carrying the crop depends on the local custom, the type of cart employed, the style of stacking, and the number of hands available for the different operations. A simple and economical method is to employ one man as builder of the stack, one man to fork the crop in the field, and two or three single-horse carts (the number

depending on the distance between the field and the stack-yard) to drive in the crop, each driver building and pitching his own load.

Different types of stacks are built in different districts. In the north it is customary to build stacks small and round; in the south they are sometimes made very large, and are, as a rule, rectangular in shape. Whichever method is employed, it is wise to lay out the stackyard with great care, always bearing in mind the possibility of pitching directly from the stacks on to the platform of the thresher, the accessibility of the first varieties to be threshed, and the reservation of the outside and exposed positions for crops that have been secured before they were in a proper condition.

When the completed stacks have settled, and when a sufficient time has elapsed to ensure that there is no possibility of heating, the stack should be thatched with sound wheat or rye straw, and the thatch well secured with ropes, or strings and pegs. The appearance of the stacks will be greatly improved if the outside is pared or trimmed to remove all loose straw and the protruding "tail" ends of the sheaves.

(For threshing, see management of threshing-machine.)

Yield.—The average yield of wheat in Britain is under 18 cwt. (4 quarters of 504 lb. per quarter) to the statute acre Crops of 27 to 33 cwt. (6 to 7 quarters) are, however, grown on good land. The weight of straw is about one and a half times that of grain, that is, the total produce is 40 per cent. grain and 60 per cent. straw. The proportion, however, varies within rather wide limits. The bushel weight averages 63 lb.

Fungoid Diseases of Wheat.

Bunt.—A casual examination of the ear of an affected plant does not reveal the presence of this disease, but when the grains are removed and broken they are found to consist of a mass of black spores, giving off a strong fishy

odour. When threshing takes place the affected grains burst, discolour the healthy wheat, and impart to the whole an objectionable odour. In this way not only is the yield of grain diminished, but its value per quarter is greatly reduced. If wheat is sown with spores of the fungus adhering to the grain, the seeds and spores germinate together and the fungus finds its way into the reproductive shoot, finally destroying every grain in the ear.

The disease can be prevented by dressing the seed with a solution of formaldehyde (1 fluid oz. of commercial formalin to 2 gallons of water), at the rate of 2 gallons to $2\frac{1}{4}$ cwt. (4 bushels) of wheat. The seed should be spread on a clean floor, the solution poured over it, and the whole thoroughly mixed by means of shovels until the solution is absorbed.[1] Care should be taken to prevent pools of liquid from collecting below the heap, otherwise the germination of the seed may be injured. The heap should then be covered with sacks, which have been rinsed through some of the solution, and left for four hours. After this the grain should be spread out in a thin layer to dry. The bags in which the seed is to be transported to the field for sowing should be treated with dilute formalin and dried, so as to obviate all possibility of re-infection. Seed which has been prepared in this way should be sown as soon after treatment as possible. A safer, if slightly less efficient, method of prevention is to dress the seed with finely powdered dry copper carbonate at the rate of $\frac{1}{2}$ lb. per sack (252 lb.) of wheat. Very thorough mixing is necessary, and a good method of doing this is to churn the mixture in an old end-over-end churn.

Smut.—This fungus attacks the ears in such a way as to destroy the grains completely, and also the pales and glumes (chaff). The whole head of the plant becomes covered with a black mass of spores. It is not possible to prevent the recurrence of the disease by pickling infected seed, as

[1] If the wheat is damp, there may be difficulty in getting it to absorb the full quantity of solution. In such a case the dressing for 4 bushels may be reduced to $1\frac{1}{2}$ gallons.

the mycelium of the fungus is present inside the apparently healthy grain. Although the fungus can be killed by immersing the grain for ten minutes in water at 128° F. this treatment is difficult to carry out in practice, and the best way to avoid further attacks is to obtain seed from an unaffected crop.

Yellow Rust.—This is a very common disease of wheat in this country, and the losses sustained through its ravages must be very high, although they are difficult to estimate. Affected plants can be recognised by the bright yellow spots on the leaves: these spots represent patches of leaf surface through which the spore-bearing organs of the fungus have burst, and the yellow powder issuing from the ruptures consists of spores.

There is no known preventative measure that gives absolute immunity from rust attacks, but there are varieties of wheat that exhibit a much greater power of resistance than others. The best known rust resister is Little Joss; Yeoman and Swedish Iron are also good varieties to sow in badly affected districts.

Brown Rust.—While yellow rust may be found on wheat at all times from early spring to harvest, and even on young plants in autumn, Brown Rust is first seen about the middle of June when the grain is beginning to fill. The fungus destroys the foliage and prevents the ears from developing properly. Wheats which resist Yellow Rust do not necessarily withstand the attacks of this species; but there is reason to believe that should Brown Rust become more prevalent, resistant wheats will be produced. At present Brown Rust is not very widely distributed.

Black Rust.—This is the well-known wheat rust of America and India, which for a long time was believed not to exist in this country, but is now known to be sparsely distributed. In this rust the spots do not occur on the leaves but on the stem, and the spores are of a very dark, almost black, colour. The Black Rust fungus has a second host, namely, the common barberry on which it passes part of its life cycle. If the wheat of a district becomes affected

with the disease, the barberry bushes should either be removed—a measure that has met with great success in U.S.A.—or varieties of wheat should be found that are resistant to the fungus.

Insect Pests.

Wireworms.—These are the larvæ of several species of click beetles, which cause an enormous amount of destruction to all farm and garden crops. When a wireworm attacks a young wheat plant it eats through the thick white portion of the stem immediately below the ground. Prevention and cure are alike almost impossible in practice, but a crop which is being attacked may be assisted by harrowing in a dressing of nitrogenous fertiliser or soot, and by rolling across the drills with a Cambridge roller. Wireworms are naturally kept in check by insectivorous birds, and these should on no account be destroyed nor their nests disturbed.

The following insects are also injurious to wheat and other cereals: the Wheat Bulb fly, the Frit fly, the Gout fly, the Hessian fly, and the Wheat midge. All are difficult to suppress, and cause considerable damage. For treatment and remedial measures the reader is referred to the Ministry of Agriculture leaflets or to works on Entomology.

OATS.

The oat is by far the most extensively cultivated cereal in this country, and is grown in every district and under widely different conditions of soil and climate. The varieties now cultivated in Britain nearly all belong to the species *Avena sativa* which is derived from *Avena fatua*. Some of the varieties grown in hot countries are derivatives of another wild species named *Avena sterilis*. Varieties of *Avena strigosa* are cultivated to a limited extent in late and outlying districts such as Shetland, and in parts of Wales. The wild oat, *Avena fatua*, is a worthless annual weed which infests the corn crops in some localities.

In the economy of the farm the oat crop fulfils a dual

purpose: it is a producer of feeding grain and at the same time supplies straw that is superior to all other cereal straws in palatableness and nutritive value, and is largely used to replace hay in winter feeding of stock. The superiority of oats as food for horses, especially for fast work, has long been recognised. The feeding of crushed oats to cattle and sheep gives good results, but they are not of a sufficiently nitrogenous nature for young growing animals unless supplemented by other concentrates, and should be blended with a food rich in protein—for example, bean meal or linseed cake. When calves are about a month old it is customary to change them over from a whole milk diet to a mixture of separated milk and fat substitute, and for this purpose crushed oats at the rate of 1 lb. to 1½ gallons will maintain the animals in health, and produce normal growth and increase in weight. Crushed oats are used in the feeding of sows and in the fattening of well-grown porkers, but if they are to be used as a feed for young pigs they should be screened to remove the coarse husk, which is apt to cause digestive disorders. The feeding of new oats is always attended by a certain amount of danger, and old oats, or at least such as have been matured in a well-settled stack, are to be preferred in stock dietary. Large quantities of oats are of course used for human consumption in the form of rolled oats, oatmeal, etc.

Milling of Oats.—In the manufacture of oatmeal the first process is to screen the oats thoroughly in order to remove impurities. The grain is then heated in a kiln until its moisture content, which is normally about 13 per cent., is reduced to about 2½ per cent. Shelling is next carried out by passing the oats between revolving horizontal stones which rub the husks away from the kernels. The material issuing from the stones is then treated to remove the dust and the husks, and the kernels or groats, after a special scouring to remove the external fibrous layer, pass to a stone mill for grinding. The ground oats are sorted through sieves into meals of various grades of fineness such as round, medium cut, and fine cut oatmeals. The yield from 100 lb.

of oats is about 60 lb. oatmeal, 17 lb. husks, and 9 lb. of dusts and residues from the sorting screens; the remaining weight is lost in the processes of cleaning and drying. The oat husks are of practically no value for feeding but are used as litter for poultry, by brewers as a mechanical aid to the draining of their mash, as packing, etc. The oat dusts and screenings may be used in mixture with other foods for stock.

Rolled oats are prepared by rolling out and drying the kernels after they have been softened with steam.

Quality of Oats.—High quality in a sample of oats is indicated by the grain being plump and well filled, by a minimum of husk and by a high bushel weight. The colour should be bright and there should be no indication of heating or sprouting; there should be no shelled grains, weed seeds, or other impurities. Oats grown in the cooler and wetter parts of Britain seem to have a higher proportion of oil and protein in their composition, and this may account for the acknowledged superiority of Scotch oats for milling purposes.

The best oat straw is fine and grass-like, and has a higher nutritive value than poor hay, but some varieties are so coarse in the stem and leaf that they are not only innutritious but also unpalatable. In order to secure the best fodder one of the noted straw producing oats should be grown, or the crop can be cut before it is ripe so that there is a check in the transference of nutrients from the straw to the grain. The proportions of grain and straw differ in different oats, and as a rule those varieties which give a high proportion of their yield in the form of straw also produce straw of fine quality.

In aiming at the greatest profit per acre the farmer looks for a variety that produces a high yield; but he has also to select, according to the needs of his stock or the demand of the market, either a variety that will give him an abundance of good fodder for home consumption or one that will yield a maximum of corn for sale. Unfortunately, these qualities are somewhat antagonistic and cannot be combined in a single sort.

As mentioned above, the oat crop is grown under a great range of conditions. At times it is grown on land that is fat with the residues of heavy manuring, when there is a great risk that the crop will be laid and will suffer heavy loss. To reduce this risk to a minimum, a variety should be grown that is either short or very strong in the straw. On the other hand, the sort of oats that will yield best under good conditions of soil and climate may give poor results when sown in an elevated or late locality, either because the plants are not sufficiently hardy, or because they take so long to mature that the crop cannot be ripened in the normal season.

The capacity of the variety for tiller formation is important because of its influence on the amount of seed that is required. Under adverse conditions a large proportion of the seed fails to produce plants, and consequently the poorer the land the greater the difficulty in getting a good stand and the greater the need for a thick seeding or, on the other hand, a good tillering variety. Our largest grained oats have the poorest tillering capacity, and on poor soil or at high elevations the cost of seeding these varieties becomes prohibitive. Where the stand is poor not only will the yield be diminished but ripening will be uneven and greatly delayed.

If oats are being grown for home consumption it is immaterial whether the natural colour of the grain be white, yellow, or black. In districts where oats are largely sold for seed, however, any lack of purity with regard to colour will render a sample unsaleable except for feeding, and consequently the greatest care must be taken when varieties of different colour are being threshed by the same machine. Yellow oats are often popular in late districts where the rainfall is heavy, because under these conditions white oats tend to acquire a dull colour while slight weathering can hardly be detected in yellow grained varieties.

Varieties.—The following is a broad grouping of the oats commonly grown in this country, together with notes thereon and descriptions of typical varieties :—

A. *Winter Oats.*—Winter oats are so called because they

are sufficiently hardy to withstand winter conditions if sown in autumn. True winter oats tiller abundantly, and for this reason they are resistant to grub attacks and need no more than the relatively light seeding of 3 to 4 bushels per acre. In the early stages the plants have a very prostrate habit of growth. The straw is long and the panicles or ears are large and spreading; the proportion of straw to grain is high, and on rich land or in wet seasons winter oats are subject to lodging. The yield of straw is generally greater than that of spring oats and the yield of grain is quite up to average. Autumn-sown oats are relatively immune from Frit-fly attacks and they are the only sorts that can be grown profitably in many districts where this pest is severe. It is recommended that winter oats should be sown early —not later than October—so that they may become well established before the advent of severe weather. A disadvantage of growing winter oats in districts where the practice is uncommon, is that the crop tends to ripen earlier than wheat or any spring cereal, and in consequence is greatly damaged by birds which are attracted from a wide area.

Examples of winter oats are Grey Winter, Black Winter, and Bountiful, the last being the most abundant cropper for good conditions but the least hardy. Marvellous is a well-known white Tartarian type of oat which is grown as a winter variety; it does not belong to the typical winter group, and while it may crop well it is not sufficiently hardy to pass through a really severe winter without a heavy mortality.

B. *Straw Producers.*—The varieties in this group are extremely hardy and can be grown in cold late districts and on poor wet soil. The tillering capacity is exceptionally good, and these sorts may be chosen where there is reason to fear grub attack. The proportion of straw in the crop is large and amounts to from 65 to 70 per cent. of the total yield; but the maximum development of stem and leaf can only be attained where there is ample rainfall. The food value of the straw is excellent. The grain tends to be

rather small but is thin skinned, and in certain varieties, *e.g.* Potato, it is very well filled and of superlative milling quality. Although the straw producing oats are not early in ripening they are nevertheless suitable for late districts, as the grain is able to mature and fill under adverse weather conditions. They are the best spring oats for soiling, for ensilage, and for making into hay.

Examples of straw producing varieties are Tam Finlay, Island Magee, Sandy, Clemrothry and Potato, the last two being rather intermediate in type between the extreme straw producers and the grain producers.

C. *Grain Producers.*—(1) Panicles equilateral and grain dark: This group contains a number of varieties suitable for poor conditions and for cultivation at high elevations, particularly where the yield of grain is more important than that of straw. The straw tends to be fine and rather easily laid; the grain is small but the yield is high.

Examples of early ripening varieties are Radnorshire Sprig and Black Bell III; late ripening sorts are Irish Tan and Black Welsh Sprig.

(2) Panicles equilateral and grain white or yellow: The oats in this group may be looked upon as the standard varieties for British conditions. For total yield and profit per acre they are usually much superior to the older straw-producing sorts. The grain is of average milling quality and the yield is high; the proportion of straw is comparatively small, being about 60 per cent. of the total produce under cool and wet conditions, and frequently under 50 per cent. in the drier and warmer districts. The straw is of fair quality for feeding and is quite good when the oats are grown in a cool wet locality. As the grains are large and the tillering power is only moderate it is necessary to give a heavy seeding.

Examples of white grained oats in this group are Abundance, Record, Victory, and Crown. Of these, Abundance is the earliest but the most liable to lodge. The other three are notably heavy croppers. Record is one of our best standing varieties and can be recommended for very

rich land. Examples of yellow grained varieties are Goldfinder, which is late, Golden Rain and Odal, which are both early.

(3) Panicles unilateral or sub-unilateral: The varieties in this class have been produced either directly or by crossing from oats possessing the one sided Tartarian type of ear. They have a showy appearance owing to the very heavy panicles which frequently carry three grains per spikelet. The straw is usually decidedly coarse and often brittle and it has a low value for feeding. The grain is very large and frequently husky; it is of the poorest quality for milling. An outstanding characteristic of the group is poor tillering capacity, and exceptionally heavy seedings are required to secure a good stand. The advantages of these Tartarian oats are that they can produce extraordinarily heavy yields when grown on rich land, that they do not lodge readily, and that a number of them are extremely early in ripening. Even in early districts it is common to grow an early variety in order to get a better distribution of labour during the harvesting season.

Examples of White Tartars are Yielder, Storm King, and Leader. Yielder is almost as good in quality as the oats in the moderate tillering group and it is early in ripening. Leader is also early but Storm King is late. Examples of Black Tartars are Black Tartar, which is late, Supreme and Earl Haig which are both rather early.

The Cultivation of Oats.

Soil and Climate. — The oat is the hardiest of our commonly cultivated cereals, and withstands the ill-effects of cold and wet; it can be ripened by a minimum of sunshine, and, in fact, develops to perfection in the dull, rainy districts bordering on our western coasts. In places more than ordinarily wet the yield of straw is very high, while in the eastern counties, where the rainfall is rather low, the yield of grain is superior and of better quality, but the straw is poorer for feeding purposes. If, however, oats are grown in

dry districts and on dry soils they are apt to be a failure, moist soil being essential for good results.

In the fen districts where the rainfall is low, very fine crops of oats can be grown because the soil receives a constant supply of moisture from underground, the water table being high. A clay loam that is supplied with abundant moisture is the best all-round soil for this crop, but black-top and peaty land give almost as good results. Should a soil suffer from lack of lime, or from the presence of an excess of iron salts, oats will be affected much less than other cereals: under these conditions barley would probably be an absolute failure.

Place in Rotation. — In the northern and western districts of Britain the oat crop is invariably the first crop taken when grassland is broken up, as no cereal does better on decomposing turf. Even after one year's "seeds," oats are preferred to wheat, because, while wheat does equally well, the fact that oats are, as a rule, spring-sown, makes it possible for the aftermath to be grazed right up to ploughing-time in December or January. In the southern districts oats are frequently taken after roots. In some clay-land localities where roots are never grown, and yet where the pasture wears out and has to be re-seeded from time to time, two crops of oats are taken, one after the other, the grass seeds being sown with the second.

Preparation and Sowing.—When the oat crop is to be taken after lea, the land is carefully ploughed about the month of December, so that the furrows will be exposed to the frost and thaw of winter, and will be easy to work into a tilth when seedtime approaches. The ploughing of lea is usually attended with more care than any other ploughing operation on the farm, because not only has the land to be turned over and exposed to the weather, but the furrow-slices have to be carefully laid so that they form regular grooves of uniform depth to receive the corn when it is broadcast. Regular, prominent furrow-slices are got by fitting special lea shares and coulters to the plough, which cut each slice so that it stands up sharply on edge. Care is also taken to

ensure that the slices are well packed together and that no spaces are left into which the seed may fall and be so deeply buried that the plants will fail to reach the surface. Where inexperienced ploughmen have been employed and gaps exist in the furrows, broadcasting can still be carried out if the field is given a light harrowing, in the direction of ploughing, in order to fill up the crevices. When the land has been prepared in this way the next operation is to sow the seed, either by hand or by means of a broadcasting machine. Spring oats are sown in March or early April at a rate depending on local conditions, the size of the seed, and the tillering power of the variety. Satisfactory crops of Potato oats can be got by sowing 1½ cwt. (4 bushels) to the acre, but with some of the new large-grained varieties as much as 2½ cwt. (6 or 7 bushels) is required. As a good man, with a couple of helpers to carry the seed for him, can sow as much as 25 acres in a day, little time need be lost in the seeding operation. The broadcast seed is next covered over by a number of harrowings with ordinary zigzag harrows, the number depending entirely on the nature of the soil; light soils require very little working, but heavy soils may require up to eight or nine harrowings before the necessary fineness of tilth is obtained. Whatever the condition of the soil, the first harrowings should be in the direction of the furrows, because if cross-harrowing is practised to begin with the tines tend to catch in the undecomposed turf, pulling the slices a little apart and so allowing the seed to slip down too far.

In many districts the broadcasting of corn has quite gone out of practice and the seed is put in with a drilling-machine. If this method of seeding is followed it is unnecessary to take any great pains in the ploughing of the lea, provided the turf be well covered and the land turned over in time to benefit by the frosts. In this case the seed-bed has to be prepared before drilling commences, and the necessary tilth can usually be obtained by the use of harrows alone. Many corn drills cannot sow as much as 6 or 7 bushels to the acre, but it may be possible to get the seed in at a thick enough rate if the bean spouts are used instead of the

cereal spouts, or the crop may be drilled in two portions, half with the furrows and half across.

When oats are taken after fallow or roots the land is ploughed, cultivated, and harrowed as often as is necessary to obtain a tilth, and the seed put in with a drilling machine. The best distance between the drills will vary according to the quality of the land. On rich soil, where the strong growing plants require considerable room for air and light, 8 to 10 in. apart is probably a suitable interval; but if the land is so poor that individual plants are incapable of growing to any great size, a greater total yield is obtained when the drills are closer together, say 6 in. apart.

Oats are frequently grown with beans, peas, or tares as a mixed crop, which can be either consumed green or ripened for threshing. The oats and peas or oats and vetches should be mixed in the proportion of about 2 to 1 and sown together; but if oats and beans are grown for threshing, it is better to sow the beans about three weeks before the oats as they take longer to ripen. Beans sown with corn will be immature when the latter is ready for cutting.

It is found that the oat crop benefits more from a change of seed than do the other cereals. If badly ripened seed is used the yield is inferior, and it is therefore necessary, particularly on poor farms and in late districts, to obtain fresh seed from time to time from a locality where the crop attains perfect development and maturity. In a late district seed should be renewed from an early district at least every three years, and even on good land a change every five years produces beneficial results.

In districts where winter oats are grown, the preparation of the ground and the autumn sowing is the same as for winter wheat, except that seeding is rather earlier.

Manuring.—While the oat crop is capable of producing a fair yield on very poor soil it nevertheless responds to liberal manuring, and it is common to treat it with nitrogenous, phosphatic and, under certain circumstances, potassic dressings. A common treatment is to give 2 to 3 cwt. of superphosphate and 1 cwt. of sulphate of ammonia at seed-

time, and if the soil is light an addition of 2 cwt. of kainit applied a month or so before sowing. The limit up to which manure can be profitably applied is determined by the liability of the crop to lodge when it becomes too luxuriant, and a short, strong strawed variety can be given a much heavier dressing than one having long and slender stems.

On good soil first-class crops of oats can be grown without the application of any manure; but if the soil is in particularly good condition and there is a danger of the crop becoming laid it is advisable to apply 2 cwt. of superphosphate, which stiffens the straw, renders the crop more secure, and hastens ripening. If oats follow another straw crop a liberal dressing of artificials will certainly be required, unless the first crop was taken after a very rich old pasture. As a rule farmyard manure does not give good results when used for this cereal, as it encourages over-development of the vegetative parts, delays ripening, and decreases the yield of grain. If oats are suffering from the attacks of frit-fly or "leather jacket," the application of a quick-acting nitrogenous fertiliser to hasten the growth of the young plants over the critical stage should never be overlooked, even if the soil is in good enough heart to warrant the expectation of a good crop without manuring.

After Cultivation.—The oat crop is usually rolled, either immediately after sowing or when the plants are a few inches high, in order to consolidate the soil about the plant roots and to encourage the rise of underground moisture. In some cases strong growing weeds may be suppressed by spudding; but if the land is very foul with small annuals a few light harrowings may be given when the plants are in the young stage. It should be noted, however, that the harrowing of oats is considered to be distinctly risky in some parts of the country, though it may be practised in others. Spraying should be resorted to in order to suppress infestations of cruciferous weeds such as runch and charlock.

Harvesting.—The degree of maturity that the crop should be allowed to attain depends on the use to which it

is to be put. When a high value is placed on the straw for feeding purposes the crop is cut early—when there is just a shade of yellow over the field—because at this time the food materials have not all passed out of the leaves and shoots, and their nutritive value is higher than when the crop is allowed to mature. Early cutting, however, interferes with the development of the grain, which is consequently inferior in quality and quantity. The best time to cut oats for general purposes is when the crop has changed from a green to a yellow colour, and about a week before it is absolutely ripe. The grain will then be able to mature in the stook and there is little risk of corn being lost in the harvesting operations. If cutting is delayed until the crop is dead ripe, shaking may cause heavy loss, especially with some varieties, before the grain is safely secured in the stacks. In cool and moist districts relatively early cutting is the rule, because more ripening occurs in the stook; in dry hot areas the plants shrivel very rapidly after cutting.

The oat crop is more liable to ferment and heat in the stack than are the other cereals, and great care should be taken to ensure that it is thoroughly dry before carrying operations are commenced. Before it is in a fit condition to lead, the crop should stand in the stook for about a fortnight, its condition being determined from time to time by examination of the juicy leaf insertions and the weeds in the base of the sheaves. Should rain, other than the slightest of showers, occur while the crop is being carried, it is advisable to discontinue the work until the crop has dried. Less care need be taken, however, if very small stacks are being built, or if the stackyard is in a position well exposed to wind.

Oat stacks are frequently built small—about 12 quarters content—and they may be constructed round wooden tripods or hollow frames, which may communicate with the outside air by means of a few drain tiles placed in position during the building operations. In this way cold air enters at the bottom of the stack and passes upwards and out through the sheaves, drying the corn and preventing heating. In some districts the danger of overheating is so great that wire and

timber drying racks, roofed with sheet iron, are erected, and into these the sheaves are packed and left until they are in a condition that allows them to be stacked with safety. When a stack does overheat it begins to lose shape and bend over towards its weakest side, and vapour may be seen issuing from its top. Such a state of affairs can only be corrected by pulling the stack down and re-setting the sheaves in stooks, or, if that is impossible, by building the contents into small easily ventilated "wigwams" containing about half a load of corn each. If the crop is in a somewhat dangerous condition when it has to be carried owing to the lateness of the season, fermentation and heating may be checked by sprinkling a stone or so of rough salt over each row of sheaves when the stack is being built.

The stacks are thatched when they have settled, and threshing takes place from time to time throughout the season according to the requirements of the stock and the condition of the market.

Yield.—The average weight of a bushel of oats is 42 lb., and the grain was formerly sold by the quarter of 336 lb. The average British yield is about 15 cwt. of grain per acre; 20 cwt. might be considered a satisfactory crop on land of medium quality, and crops of 35 cwt. and upwards are occasionally recorded. The yield of straw depends on the nature of the variety grown and on the rainfall. Grain producing varieties when grown under moist conditions yield about 40 per cent. grain, or one and a half times as much straw as corn.

Fungoid Disease.

Smut.—When plants are affected by this disease the reproductive shoots issue from their sheaths covered with a mass of black fungus spores, though in other respects the plants appear to be perfectly healthy. The spores, which are those of a fungus feeding on the nutrients provided by the plant for the development of the grain, are carried by wind and rain to healthy grain and lie dormant until the following year. When the grain is sown they become active

and produce a mycelium which enters the young plant, finds its way to the ear, and produces towards the end of the season a fresh crop of spores. Some crops contain a large proportion of these black heads, and the total loss due to the disease is very considerable.

The occurrence and spread of this pest can be completely checked by steeping the seed corn in a solution of formalin, 1 oz. mixed with 2 gallons of water being sufficient to treat 4 bushels. The older treatment with copper sulphate, commonly used with wheat as a preventative for bunt, does not give satisfactory results, because the oat grains absorb so much of the solution that many of the germs are killed.

Insect and other Pests.

Leather Jackets.—These are the larval forms of species of crane-flies, popularly known as daddy-longlegs. They attack all farm plants, but cause more apparent damage to oats taken after old grass than to any other crop. The adult flies appear from June to about the end of September and lay their eggs on grassland, preferring that which is rough and moist. The larvæ feed till the following spring before passing into the pupal stage, and during this time they not only attack plant roots but they come to the surface at nights and gnaw through the leaves and stems. The loss is usually most severe in a backward spring when the crop cannot grow away from the attack, and the damage may be accentuated by birds pulling the plants out of the ground in search of the larvæ.

When there is reason to expect grub attack in oats a multi-tillering variety—*e.g.* Potato—should be grown, because it will be much better able to recover from the pest than one that only tillers slightly. Practical measures to combat the leather jackets are to stimulate the affected cereal with a top dressing of quick acting nitrogenous manure such as nitrate of soda, and to destroy the larvæ by means of poison.

To prepare poison bait for one acre, mix 1 lb. of Paris green with 30 lb. of bran or thirds and 2 gallons of water, to

which a little treacle may be added. The material should be sufficiently moist to cause the poison to adhere, yet dry enough for convenience in sowing. The mixture should be broadcast over the affected crop, and it is found that the best results are got when this is done on a moist warm night.

Frit-fly.—The larvæ of this fly cause damage to all cereal crops and grasses, but in this country the oat crop is the greatest sufferer. Early in the season the maggots do damage by feeding in the hearts of the young plants, and the broods that hatch out later in the year attack the immature grain in the developing ears. The outward manifestation of the spring attack is a yellowing and a stunting of the crop. A close inspection shows that the central shoots and one or two of the first tillers are yellow and badly developed, while a few of the youngest tillers and the outer leaves are healthy and green. The maggots, which are $\frac{1}{8}$ in. long, can be found in the hearts of the stunted stems, and a few pupæ may be found behind the outer leaf sheaths.

The first brood of flies appears in April and May, and egg-laying takes place shortly afterwards. The females prefer to lay on very young plants and will avoid crops that are strong and in a forward condition. It is advisable, therefore, in districts where the fly is a serious pest, to sow the oats early in March and to manure them liberally so that they may be strong and well established before the egg-laying season commences. Winter oats suffer to a far less degree than the spring sown crops.

The Stem Eelworm.—Nematode worms attack many field and garden plants, the chief farm crops affected being oats and clover. An oat plant parasitised by the eelworm suffers in much the same way as one attacked by frit, but if the stem base be examined it will be found to be swollen or "tulip rooted." As the worms are only $\frac{1}{25}$ in. in length their presence should be confirmed by the use of a magnifying glass. Eelworm and frit attacks frequently occur simultaneously, and where the frit larvæ are discovered the other parasites are apt to be overlooked.

The only remedy is to encourage vigorous growth by nitrogenous top dressings, although the application of sulphate of potash is said to have a direct toxic action on the worms.

BARLEY.

Barley has been cultivated from time immemorial, and is believed to have been brought to England from Western Asia. It is widely grown in all subtropical and temperate countries, and very large areas are devoted to its cultivation in all parts of the British Isles. It is used for human food and is an important bread cereal in some parts of Europe. In this country, however, barley flour is little used, but pot- and pearl-barley are in considerable demand for culinary purposes. An interesting feature in the composition of barley is the nature of its protein matter, which is quite different from the gluten of wheat and goes into solution when boiled in water; this extract, known as barley water, is largely used as a nitrogenous food for infants and invalids. For the feeding of farm stock barley and its by-products have a very high value. The husk content of the grain is much lower than in oats, and this makes the cereal unsurpassed for the feeding of pigs; but it should always be crushed or soaked before use as it is extremely hard, and the animals are apt to swallow it without sufficient mastication. The straw is soft and friable and makes poor litter; it is usually cut when the grain is dead ripe and then contains little material of feeding value; but if it is cut early it approaches oat straw in quality, and is at all times superior to wheat straw for feeding purposes. All the best barley, however, is used for malting, and its degree of suitability for this purpose determines its market value, the straw being strictly a by-product.

Malting of Barley.—Barley is largely used for malting because of its high percentage of starch, and the object of the process is to bring about certain changes that enable the starch to be converted into sugar. When barley is placed in a suitable environment of air, moisture,

and temperature, a number of ferments or enzymes are produced which convert the material of the endosperm into soluble substances suitable for transference to the embryo for the nourishment of the growing stem and roots. The chief enzyme produced is diastase, which converts starch into sugar, but protein and cellulose dissolving ferments are also formed. Maltsters take advantage of this natural process to obtain fermentable sugars from the contents of the grain. The first stage in the conversion of barley into malt is to soak the grain in water for two or three days, so that it will absorb enough moisture to activate its latent life; then it is spread out on the malting floor to encourage its germination. Its temperature is carefully controlled and it is turned over for aeration from time to time for about twelve days, by which time the rootlets have developed and the plumule has grown to about two-thirds of the length of the grain. The sprouted seeds are then removed to a kiln and thoroughly dried; they are then dressed to remove the dry rootlets, which are placed on the market under the name of malt coombs, and the finished malt is ready for marketing or storage.

When the malt is used for brewing it is crushed and mashed in water, when the ferment diastase once more becomes active and all the remaining starch is brought into solution as a sugar. The residue of the grain, consisting of the insoluble carbohydrate and protein materials, is removed and marketed under the name of brewers' wet grains, or, to reduce its weight and facilitate transportation, it may be desiccated and placed on the market as dry grains. A quarter of barley (448 lb.) will produce about 336 lb. of malt, which should yield 80 to 100 lb. of soluble material or brewers' extract.

Quality of Barley.—To judge the quality of barley for malting purposes the points to consider are those that indicate the greatest possible yield, and the highest possible quality of extract from a given weight of the grain. As the amount of the extract depends on the carbohydrate content, and varies inversely with the proportion of oil and protein, the

best samples possess a maximum of starchy material and show the least possible flintiness: the grain should be plump, and the skin fine and wrinkled. The colour of the barley is also important as dark coloured grains can only be used in the production of dark coloured beers and stouts, while for pale ale a bright colour is necessary, and as light barleys are somewhat scarce they always command a higher price. Red ends to the grain indicate that the crop was cut before it was ripe. As barley has to be germinated and a solution of extract prepared from the malt, it is essential that it should be in a sound, mature condition, and it should be carefully prepared so that it contains no broken or damaged grains and no foreign matter. If the crop is severely treated in threshing, owing to the concave being set too close to the drum, the grains are frequently broken or skinned. Broken grains die and form a medium for mould growth, but they can be removed by modern machinery. Grain that is skinned or that has the skin loosened, however, is very objectionable as these conditions lead to abnormal absorption of moisture during malting. The threshing, then, should be carefully performed and the grain well screened if it is to realise a good price. It is almost needless to state that any heating and weathering that detract from the appearance and odour of the sample will have a serious influence on the marketableness of the crop. Barley varieties should be kept strictly pure, because in the malting process it is essential to have a uniform sample; it has been found that different sorts of barley do not germinate at the same rates and have to receive different treatments; mixed samples are difficult to malt and never produce satisfactory results.

From the farmer's point of view a variety must produce quantity as well as quality; but most of the best sorts in wide cultivation are not only capable of producing good yields but of bringing the highest awards at the brewers' exhibitions. It is a fallacy that quality can only be obtained when the crop is cultivated on impoverished soil that has a restricting action on the growth and yield.

Varieties of Barley.—Barley is grown under a wider

range of conditions than any other cereal; it is cultivated in Norway and it is grown in Africa. Varieties that prove most profitable under these extremes of climate are unsuitable for temperate conditions like our own, and it is reasonable to expect that the cultivated varieties of this grain plant will exhibit many striking differences in form and character. Generally considered, however, three distinct races are commonly recognised: (1) Six-rowed barley; (2) bere or four-rowed barley; and (3) two-rowed barley.

In the six-rowed barley each floret in the spikelet is fertile, and six rows of grains are attached to the central axis. It is probable that this race of barley is a very ancient one. The straw is short and strong and the ears are very compact; the grain is irregularly shaped, badly filled, poor in colour, and generally unsatisfactory for brewing purposes. The race is extremely hardy and is largely grown as a catch crop, being sown in autumn and cut for soiling purposes in spring, or it may be folded for stock. On dry chalky soils it is sometimes grown as the chief cereal for feeding purposes, taking the place of oats.

Bere or four-rowed barley has all the florets fertile but only two regular rows of grains, the remaining four rows being irregularly placed on the lax ear in such a way as to give it the appearance of having four rows only. The race is extensively cultivated under the severe climatic conditions of North-West Scotland and Northern Europe. The grain has the inferior malting qualities of the six-rowed type; it is used as a food for stock and to some extent in the manufacture of alcohol, but it is not good enough for brewing. Bere may be autumn sown and used as a catch crop for spring fodder, either alone or in a mixture with other autumn sown species.

In two-rowed barley only the central floret of each spikelet is fertile, the lateral florets being infertile or staminate. These barleys are by far the most widely cultivated, and are the sorts used in the best barley-growing districts of the world for the production of grain of the finest malting quality. There are many different kinds of two-rowed barleys, but

the majority are varieties of the Archer, Goldthorpe, or Chevallier types, or products of their crossing.

Chevallier Barley.—This variety has descended from a few ears collected in Suffolk in 1823. The grain is plump, thin skinned, and light amber coloured; in appearance and colour it is superior to all other sorts, and it is probably the most favoured of the malting barleys. It is largely grown in the best quality-producing districts, and has few rivals in Norfolk, Suffolk, and the southern counties; in Lincolnshire it competes with the other well-known sorts. When the crop is ripe many of the stems bend over at the uppermost node and have a knee-bent appearance, but the heads do not readily break off. The straw is long and slender, and the variety will not stand heavy manuring. It is not suitable for cultivation on the richer or heavier soils, nor in any but the drier climates.

Goldthorpe Barley.—This variety was obtained in 1889 from a single ear, which was of the old-fashioned sprat or fan type, but had grain of larger size and better colour. It is generally grown in the barley districts of Scotland and the North of England, and in all cases where the soil is rich and fertile, as, being strong in the straw, it does not lodge readily. Although in appearance it is somewhat inferior to Chevallier, its nitrogen content is probably lower than in any other sort, and it is a favourite with the brewers. Its chief disadvantage is that it tends to become neck-bent, that is the straw bends over immediately below the ear, and if cutting is delayed after the crop is ripe, serious loss may take place owing to the ears breaking off and falling to the ground.

Archer Barley.—This is an old type which used to be known under several names, and is still the most popular sort in Ireland and S.W. England. A number of characteristics distinguish it from the other well-known varieties; it is distinctly late, ripening about a week after Chevallier; it has a very short upper internode or neck and it rarely becomes knee-bent; the colour of the grain is not amber but greyish; the rachilla is short and bristly. The inferiority

of this sort to Chevallier barley is limited almost entirely to its appearance, the difference in nitrogen content and production of extract being very small. Experiment in Ireland showed that Archer produced a heavier yield than Goldthorpe, though of rather poorer quality, for which inferiority, however, the difference in yield more than compensated, on a comparison of values. Even in England barley of this type, which can be well treated because of its strong straw, is probably more prolific in its yield of grain. Because of its late ripening it is essential that it should be sown early.

Standwell, Maltster, Binder, Plumage-Archer, and Spratt-Archer are commonly cultivated varieties which belong to either the Goldthorpe or Archer types, or are products of their crosses.

Cultivation of Barley.

Soil and Climate.—Barley can be grown under almost any conditions of soil and climate, but all conditions do not give equally good barley for malting purposes. England produces the highest yield and the best malting barley in the world, but barley is only cultivated in certain parts of the country, and the finest samples are obtained from a limited number of districts. Probably our best barley is grown in Norfolk, Suffolk, and Cambridgeshire, but there are a number of belts in different parts, mostly bordering on the sea coast, that give almost equal results in yield and quality. Of these the best known are Fife, East Lothian, and Berwickshire in Scotland, East Yorks, Lincolnshire, Somerset, and Devon in England, and Galway and Wexford in Ireland. In Britain, then, the barley districts are the southern and eastern counties, which are the regions of maximum sunshine and least rainfall. Considering the temperature and rainfall of these districts during the growing season, it is found that where the rainfall is almost constant, as along the east coast, the cooler the temperature the greater the yield of barley: and in districts where the average temperature is about the same, the best crops are got where the rainfall is least.

Barley does best in a cool, dry district, while a hot season produces pinched, hard, and inferior samples. The best soil is light, free, open in texture, and of a nature suitable for turnip growing and sheep farming; it is often thin and naturally poor, and has to be kept in condition by feeding off the root crops. Probably the best barley is grown on the Chalk, Tertiary, and Recent deposits, and it is seldom that a good sample is obtained from heavy or high conditioned soil that is suitable for wheat, or from peaty soil. It is essential that the soil should not be acid, otherwise barley will not thrive, indeed it may die out entirely.

Place in Rotation.—Barley is usually taken after a root crop, and in the typical sheep and barley districts on the chalk formations, as well as in many other arable districts, it follows roots consumed on the ground by sheep. On thin, light soil this treatment leaves the upper layer impregnated with manure, consolidated by the treading of the animals, and in excellent condition for the cereal crop that is to follow. In good districts where the land is in high condition the feeding off of a root crop is likely to leave the soil too rich, when the succeeding barley will be nitrogenous, dark in colour, and liable to lodge. If barley has to be grown under these conditions a strong strawed variety should be selected, the most suitable sorts being of the Goldthorpe type.

Probably the finest samples of barley are grown, not after roots, but after another straw crop. In this way the first crop removes the excessive richness, and the barley, feeding upon the diminished quantity of soil nitrates, tends to be of a more starchy nature and a better colour; the sample is also more even because the inequalities of manuring produced by the sheep feeding are more or less removed by the first crop.

Preparation and Seeding.—The nature of the preparation depends on the condition of the soil; but on land that tends to become poached by the treading of sheep, it is desirable to perform the ploughing early so that the furrows are exposed to frost and thaw, and the detrimental effect of

the puddling is removed. On light land, where the texture is not injured by sheep, ploughing can be performed any time before it is necessary to prepare the seed-bed. As barley requires a fine tilth, and at the same time a good firm bottom root-hold. the ploughing should not be deep (4 in. is often sufficient), and the tilth should be prepared by dragging, harrowing, and rolling as often as is necessary. The grain is put in with a seed drill at the rate of 1¼ to 1½ cwt. (2½ to 3 bushels) per acre in England, and 2 cwt. (4 bushels) in Scotland. It is found that this method of sowing gives more satisfactory results than broadcasting, because the seed is put in at a regular depth, the plants germinate together, reach maturity at the same time, and produce an even sample of uniform merit. When the drilling is completed the field is given a harrowing and finally rolled.

Barley has a shorter period of growth than the other cereals, and in a late season satisfactory crops can be obtained from seed put in as late as May. Nevertheless the best crops and the finest samples are got when seeding takes place as early as February or the beginning of March.

Manuring.—When barley is grown on land in high condition, or on land where a root crop has been consumed, it is not as a rule necessary to supply any artificial fertilisers; but under conditions where the land is so rich that luxuriant vegetation and late ripening may endanger the quality of the crop, 2 to 3 cwt. of superphosphate will improve the standing power of the straw, the quality of the grain, and hasten the crop to maturity. If barley is taken after another white crop, or after roots carted off, it is usually necessary to give a more substantial manuring, as, with its short growing season, it depends more on a supply of readily available foodstuffs than does wheat. A suitable dressing would be 1 to 1½ cwt. sulphate of ammonia and 3 cwt. of superphosphate per acre applied at seedtime. Potash is excellent for producing plump, bold samples; but unless the soil is of a light sandy nature the potassic fertilisers do not as a rule give a return commensurate with their cost, though

they may be applied because of their beneficial influence on the clover seeded under the crop. Farmyard manure is too rich in nitrogen for barley, and its use leads to a decided falling off in quality.

After Cultivation.—The barley cultivations carried out between seeding and harvesting are very similar to those of the other cereals. The land is usually rolled when the plants are a few inches high, and a harrowing may be given to provide a surface mulch and to suppress annual weeds. Hand-hoeing and thistle spudding are practised when necessary.

Harvesting.—Barley is allowed to become dead ripe before it is cut. When this state of maturity has been reached, the ears tend to bend over, the individual grains are hard with pale yellow wrinkled skins, and the straw is practically dry. If the crop is cut too soon an uneven sample results, and the maltster is unable to obtain that uniformity of germination so necessary to the production of high-class malt. At one time barley was cut with a scythe or mower and "made" in the same way as hay. It was exposed in the swath and turned from time to time so as to benefit by the bleaching action of the sun, and finally carried and stacked in the loose state. Although this method of harvesting is still practised in a few of the chalk districts where small crops of high quality grain are grown, it has almost entirely gone out of fashion. With the advent of the binder and the rise in cost of labour, the crop began to be cut and bound in the usual way, with no serious detriment to the quality; in fact, almost all the prize-winning barleys at the brewers' exhibitions are bound and stooked in the usual way.

With good weather the crop is generally ready for carting out of the shock in about a week, but during periods of wet weather carting is greatly delayed. The straw is of a soft nature, and holds rain readily, and the grain, which is sparingly covered by chaff, becomes dark coloured and poor in appearance. When the crop has been used to nurse clover seeds the bottoms of the sheaves frequently contain an

abundance of soft green herbage, and the drying period in the stook is thus greatly prolonged.

Barley is stacked in the usual way, and if it is secured in a dry, sound condition its colour generally improves very considerably before threshing takes place. If, however, the corn is badly secured or in a wet condition it changes in the stack to a dark inferior colour, and in bad cases becomes mouldy. It seldom comes out of the stack having the same quality as when it was put in: it either improves or deteriorates.

Yield.—The weight of a bushel of barley varies a great deal. A good sample should weigh 56 lb., although prize-winning barleys are heavier. The bushel weight is indicative of the plumpness and fullness of the grains, light weights being got when the "peas" are thin and contain a high proportion of husk. The average yield is about 16 cwt. (4 quarters of 448 lb.) to the acre, and about the same weight of straw, that is 50 per cent. grain and 50 per cent. roughage. The yield of grain may reach or exceed 30 cwt. under good conditions.

Fungoid Diseases.

Covered Smut.—Barley suffers from the attacks of a fungus causing a loose smut which is very similar to loose smut of oats (except that it cannot be cured by steeping the grain), but it is much more commonly attacked by covered smut. In this disease the ears issuing from their sheaths are not covered with sooty powder but the grains, though normal in outward appearance, contain a mass of black spores enclosed by the thin adherent chaff. The grains remain whole until threshing takes place when the concussion breaks them up and the spores are liberated. Not only do the spores infest healthy barley grains, but they discolour the whole sample and reduce the market value of the crop.

The transmission of covered smut to the next crop can be prevented by soaking the seed in a formalin solution as in the treatment of oats against loose smut.

Leaf-Stripe.—This disease, known as *Helminthosporium gramineum*, causes the leaves of the young plants to wither and die off, and an examination reveals longitudinal dark coloured stripes on the laminæ. Affected plants produce blind ears and the loss is therefore much greater than is occasioned by the reduced assimilating surface. Another species known as *Helminthosporium teres* produces spots on the leaves; the disease does not occur regularly throughout the crop, but in isolated patches; it does not, however, cause blindness.

Leaf-stripe can be partially controlled by soaking the seed in formalin in the usual way.

Insect Pests.

The **Ribbon Footed Corn-fly** or **Gout-fly** is a pest that causes considerable damage to barley and also to wheat. The flies lay their eggs on the plants, and when the larvæ hatch out they eat their way into the stem below the ear while it is enshrouded by its surrounding leaves. They eat a groove down the axis to the first node, which is so characteristic that it is quite sufficient to confirm the nature of the attack. The plants become stunted and "gouted" in appearance and fail to produce grain.

As egg-laying takes place in May and June, and again in September, either autumn or spring sown plants may be attacked. In districts where the fly is troublesome it is therefore advisable to sow winter wheat and barley late, and the spring crops should be put in early so that they will be well established before egg-laying commences. If a crop is obviously suffering badly from an attack, it may be stimulated into producing a certain amount of grain which may pay for the labour of harvesting, by giving it a quick-acting nitrogenous dressing; but where the ears are practically all grainless it should be eaten off by sheep.

RYE.

It is probable that our cultivated varieties of rye were obtained originally from a wild perennial species found in Eastern Europe. Rye is largely used as a bread cereal in Germany and Russia, and resembles wheat in having grain easily separated from the chaff in threshing, and in yielding corresponding offals on milling. In this country it is mostly cultivated as a forage crop, but also to some extent for its straw; some, of course, is grown for seed. Rye straw is longer, stronger, and wears better than the straw of wheat. It is largely used for thatching, packing, etc.

Varieties.—There are comparatively few varieties of rye in cultivation, and the sorts commonly grown in this country are Common or Winter rye, Spring rye, Russian, and Giant rye. The winter varieties are larger and longer of grain, longer and stronger of straw, and are exceedingly hardy. The summer sorts grow with great rapidity but do not produce such a bulk of foliage, and their grain is considerably smaller than that of the winter ryes; the yield is less, and the quality for bread-making is inferior.

Cultivation of Rye.

Soil and Climate.—Rye is a drought resisting plant which thrives under a great variety of conditions and is productive upon almost any class of soil. When grown for grain on good soil it is usually less profitable than the other cereals, and its cultivation is therefore confined to districts of poor, dry, light land that produce inferior wheat and oats. This does not mean that rye does best on thin soils: it does best on good loams, which, however, yield more profit under other crops. It has an additional advantage in late districts in that it ripens early. When rye is grown on good land it is mostly cultivated for forage purposes, and it is extremely valuable for feeding off or for soiling.

Place in Rotation.—When rye is grown for seed it takes the place of any of the other cereals in the rotation, and is usually taken after roots or clover. When grown as a

catch crop, as it usually is, it frequently follows another white crop and is sown in the autumn for feeding off in the spring. Summer varieties which mature rapidly are often employed in continuous cropping rotations, and may be seeded in the spring after a winter crop has been consumed.

Preparation and Sowing.—The seed-bed is prepared as for wheat, and the grain may either be broadcast or put in with a drilling machine. From 1 to 1½ cwt. (say 2 to 3 bushels) are required to sow an acre, and seeding takes place from two to three weeks before wheat sowing commences.

Manuring.—As a rule, the only manure the crop requires, when it is taken after roots or seeds, is 1 cwt. of nitrate of soda in spring, and if the land is in good condition this should not be necessary. There is always a danger if the crop be heavily manured of the very long straw bending over near the ground and becoming laid.

Harvesting.—Cutting takes place about a fortnight before wheat harvest commences, which is about the beginning of August in medium early districts. The crop is bound and stooked in the usual way, and, as the straw contains very little sap, carrying can take place a week or so after cutting. When high quality rye straw is required for special purposes it may be cut before the ear has filled, then dried and used: this avoids the threshing process which damages the stems considerably. Where it is grown as a forage crop it must be cut early—before it shoots—as towards the end of its growing period it becomes hard, dry, and unpalatable.

Yield.—The average weight of a bushel of rye is about 58 lb., but much depends on the variety, the winter sorts weighing up better. The yield varies from 12 to 16 cwt. (3 to 4 quarters) of grain and 30 cwt. to 2 tons of straw per acre. Yields of grain up to 25 or 30 cwt. have been recorded.

CHAPTER II

THE POTATO

THE potato (*Solanum tuberosum*) was introduced from South America in the sixteenth century, but in those early days it was regarded rather as a curiosity than as an article of commerce, and it was not until about two centuries later that it was cultivated to any extent on a field scale.

As a producer of human food the potato is the most valuable crop grown in this country; it is cheap, and its dietetic value is considerably higher than was for a long time supposed. As a food for stock, especially pigs, it is of great importance, but because only a certain proportion of the crop is marketable and there is a considerable residue of diseased, damaged, and small tubers, which can be used only as stock food, it is not customary to cultivate the crop for this purpose.

The potato crop has, however, a number of disadvantages. Its bulky nature makes it not only costly but difficult to market, and for this reason, even where the soil is suitable, very few potatoes are grown at any great distance from market centres. Again, even where a ready market is at hand, the large number of workers required for timely lifting and setting restricts cultivation (on a large scale) to districts where casual labour is available. The crop is also somewhat speculative, because in good years the market is liable to be glutted and the potatoes have to be sold below the cost of their production. Nevertheless, taking one year with another, probably more profit is made from potatoes than from any other farm crop.

Quality of Potatoes.—The farmer, of course, requires a variety that will produce the greatest possible yield per

acre, but he must also consider the buyer's point of view or his crop will not meet with a ready sale. Apart from yield the most important points are keeping quality and resistance to disease. Potatoes have to be stored for considerable periods, and it is disastrous if a large proportion decays or deteriorates in the clamp, as a good crop may in this way be reduced to an inferior one, and the expense of picking over diseased tubers is extremely heavy. Not only should the variety be capable of resisting disease and decay in the pit, but it should withstand the effects of the many and serious pests that beset it in the field, the most devastating of which are blight, wart disease, and the degeneration diseases. No varieties are absolutely immune from blight though many are highly resistant; but, luckily, there are varieties that, even when grown in highly infected soil, are not affected to the slightest degree by wart disease, and it is still possible to grow potatoes in localities infested by the spores of the disease. For general economy it is also advisable to obtain varieties that develop their tubers at a suitable depth below the surface; if they protrude above the soil they become greened by the light and are then difficult to sell, while if too deep they are difficult to get out with an ordinary potato digger and, apart from the numbers that are sliced and damaged, many are left in the ground to become a source of trouble in the following crops. The potato is the principal cleaning crop in the rotation of many farms, and a variety that develops a large amount of surface growth and leafage is most efficient as a smotherer of weeds, and most likely to leave the soil in a clean condition. There are varieties that cannot be cut for seed as they do not grow well from cut sets, while at the other extreme there are potatoes that give excellent yields when cut to a single eye.

From the point of view of the consumer the cooking quality of the variety is most important. In England white fleshed sorts that become "mealy" on boiling are generally the most popular, but on the Continent yellow fleshed potatoes possessing a waxy texture are preferred.

Potatoes that produce either very large or very small tubers are not in demand, and varieties that are irregular in shape or deep in the eye, and are consequently difficult to peel without occasioning considerable loss, are never popular. The colour of the skin varies through a wide range—purple, red, pink, red-eyed, russet and white, all being common, but the white sorts are best known and most appreciated. The shape may be round, oval, or kidney, but this is of little importance provided the tubers are regular, though round varieties are most suitable for potato-peeling machines.

Varieties.—An enormous number of different kinds of potatoes are now on the market. Potato varieties are comparatively short-lived; even if they are phenomenally successful for a few years they generally deteriorate, become susceptible to disease, and their yields fall off to such an extent that newer and more vigorous sorts are taken up in their place. Why should potato varieties be so short-lived? A variety consists, strictly speaking, of a great number of parts of the same individual mother plant, and one view is that degeneration is the inevitable consequence of the old age of this plant, or, in other words, the result of continued vegetative reproduction. If this conception proves to be correct, then it will be necessary to maintain for all time a supply of new sorts produced from true seed. On the other hand a great deal at least of the observed deterioration is not really a loss of vigour or constitution but is due to the accumulation in the stock of virus diseases (see p. 216).

When new varieties are being raised the chief objects kept in view are, the production of a good yield, resistance or immunity to disease, and good shape, colour, keeping, and cooking qualities. The commonest way to raise new sorts is to sow the seed from a self-set potato berry. In the case of organised plant breeding, crosses are made between selected parents by emasculating the plant on which the berries are to be grown and impregnating the stigmatic surface with pollen from the other parent. When the berry has matured, the seeds, which may number two or three hundred, are

sown. The seedlings which develop exhibit many forms and characters differing from the parent types. The great majority are as a rule inferior or unsuitable: some develop long stolons and few tubers; most are poor croppers and many are quite useless because of their irregular shape and appearance; only a few are of sufficient merit to justify their propagation until they can be given a fair trial on a field scale. A number of experimenters have used certain wild species of potatoes for crossing purposes, with the object of imparting hardiness and disease resisting capacity to our cultivated sorts.

Proportion of Total Acreage under Potatoes in Scotland occupied by leading Varieties in 1926.

Variety.	Acreage.	Percentage of Whole.
1st Earlies—		
Epicure	9,294	61
Eclipse	2,006	13
Sharpe's Express	1,482	10
Duke of York (including Midlothian Early)	1,358	9
Other First Earlies	1,060	7
Total area	15,200	100
2nd Earlies—		
*Great Scot	11,026	56
British Queen	5,786	29
*Ally	815	4
*Arran Comrade	578	3
Other Second Earlies	1,580	8
Total area	19,785	100
Maincrops—		
*Kerr's Pink	30,471	34
King Edward VII.	20,146	23
Arran Chief	11,122	13
*Golden Wonder	9,586	11
*Majestic	5,684	6
Field-Marshal	2,385	3
Up-to-Date	2,023	2
Other Maincrops	7,691	8
Total area	89,108	100

* Immune from wart disease.

The different varieties of potatoes are generally classified according to their earliness. There is a gradation from the extreme early sorts to the very late maincrops, but (although there are no real dividing lines) potatoes are classed as Earlies, Second Earlies, and Maincrops. Sometimes the terms Early Maincrop, Early Second Early, etc., are also used.

The comparative popularity of the innumerable varieties under cultivation can perhaps best be deduced from the table on p. 189, taken from the statistics of the Scottish Board of Agriculture. Unfortunately corresponding figures for England are not available, but though small differences exist, it is improbable that there is any great dissimilarity between the two countries.

In the following descriptions leading varieties have been selected because of their wide cultivation; but it must not be inferred that they are necessarily the best sorts at present on the market, lack of space necessitating the exclusion of many new and promising varieties that are likely to be widely grown in the near future. It is probable that the general tendency will be for the immune varieties to increase in popularity at the expense of the older susceptible sorts. The descriptions of the morphological characters of the varieties are taken, with the permission of the Controller of H.M. Stationery Office, from "The Maintenance of Pure and Vigorous Stocks of Varieties of the Potato" issued by the Board of Agriculture for Scotland.

1st Early Varieties—*Epicure.*—Tubers: round, irregular; skin white, turning pink on exposure; eyes deep, ridged, with raised eyebrows; flesh white; sprouts pink.

Foliage: haulm upright, rather robust and tall for an early; leaf dark, glossy, drooping; leaflets long and narrow, the last pair having waved margins, and pointing forward to overlap the terminal which droops. The stem develops a pink colour.

Flower: white, not blooming freely; buds dark with green tips.

This variety is not immune from wart disease and is

susceptible to blight and blackleg. Strictly speaking it is a second early but it bulks so early that when lifted in an immature state its yield exceeds that of any of the first earlies. It is more resistant to frost than any other first early, and is the most popular potato for the early districts in Scotland. The eating quality is decidedly poor and the deep eyes are rather objectionable.

Eclipse.—Tubers: oval to oval pointed; skin white; eyes shallow and almost on the point; flesh white; sprouts pink.

Foliage: haulm of medium height and spreading; stems pink in colour and solid before maturity; wings waved; leaflets broad, small, dull, light to medium green. There is a pink tinge at the base of the leaflet stalks, and on the margins of the leaflets, at an early age.

Flower: white, infrequent; buds hairy and dark pink with green tips.

Eclipse is not immune from wart disease and is susceptible to blight and blackleg. It produces good crops which bulk early and can be marketed in an unripe condition. The eating quality is poor.

Sharpe's Express.—Tubers: kidney (pear-shaped); skin white; eyes on point small and saucer-shaped, those on sides having raised eyebrows; flesh white; sprouts pink.

Foliage: haulm upright to spreading; leaves long, medium green and bright, with a large number of secondary leaflets which give the leaf a crowded appearance; leaflets distinctly pointed forward and overlapping. The last pair of leaflets often twist round the end leaflet, which curls up to fit into them.

Flower: red-purple, infrequent; buds with pink markings.

Although this variety is non-immune and rather susceptible to blight it is on the whole more resistant to disease than the other common first earlies. It is a favourite variety in the early district of Cornwall. The eating quality, when grown in the south, is distinctly good, but if the crop is lifted very early it contains an unduly large proportion of small tubers.

Duke of York.—Tubers: kidney (pear-shaped), thick;

skin yellow, rough at maturity; eyes very shallow and on the point; flesh yellow; sprouts faint pink.

Foliage: haulm of low to medium height; open and straggling; leaf open and long; leaflets medium green, dull, thick and long.

Flower: white, seldom formed: anthers pale and malformed; buds with long green tips.

This variety is not immune from wart disease and is susceptible to blight, blackleg, and leaf roll. It is the earliest of the popular first earlies to reach maturity. The cropping capacity is poor but the eating quality is exceptionally good, and the variety is a favourite for garden cultivation. Owing to its open habit of growth it covers the ground badly and may allow the land to become foul with weeds.

2nd Earlies—*Great Scot.*—Tuber: round (somewhat flat), heel generally dented; skin pale yellow, but during growing season white at the eyes; eyes shallow to medium, saucer-shaped, and on shoulder of tuber; flesh white; sprouts deep pink.

Foliage: haulm tall, upright. Leaves fairly open, glossy and dark; leaflets thin, the end leaflet dropping to the perpendicular. Stem deep pink at the base, and not branching freely above ground.

Flower: white, but generally dropping off unopened, except in bolters which generally flower; anthers pale; buds dark.

Great Scot is immune from wart disease and resistant to mosaic, but it is susceptible to blight and blackleg. It is an exceptionally heavy cropper and responds well to liberal manuring; indeed it yields so well that it is largely grown as a maincrop. The eating quality is only fair.

British Queen.—Tuber: oval to oval pointed; skin white; eyes medium and on point of tuber; eyes on sides of tuber, having eyebrows long and raised; flesh white; sprouts pink.

Foliage: haulm of medium height, spreading; stems tinged red-purple, branching; branches rigid, wings slightly waved at the tops. Leaf open and rigid; leaflet broad,

medium to dark green and bright; end pair do not overlap the terminal.

Flower: creamy white, large and profuse; flower stalks bronze coloured; buds dark.

This variety is not immune from wart disease and is susceptible to blight, blackleg, and leaf roll. It is the most widely grown variety for the second early market, much of the Great Scot crop being marketed late. It is a splendid cropper and is of excellent eating quality, even when lifted green.

Ally.—Tuber: round to oval (flat); skin yellow; eyes shallow, saucer-shaped, few, close together and on the shoulder, flesh white; sprouts faint pink. Second growth takes the form of cracking.

Foliage: haulm of medium height, spreading, dark grey-green; stems green; leaflets long and hairy, with a dull thick appearance, towards maturity becoming rather glossy; secondary leaflets inconspicuous. Terminal leaflet often joined to one or more laterals.

Flower: white; anthers generally lemon coloured and malformed. Buds green with a pink tinge.

Ally is immune from wart disease. When grown on good land it produces an exceptionally heavy crop of coarse potatoes having poor eating quality. In some places it is in demand for the chip trade.

Maincrops — *Kerr's Pink.* — Tuber: round (somewhat flat); pink; dented at heel; eyes usually medium but sometimes deep; flesh white; sprouts pink.

Foliage: haulm tall and branching; very vigorous; stem strong, tinged pink; wings distinctly waved; leaf rigid and fairly close; midrib pink; leaflets dull, medium to dark green, large, broad and pointed; secondary leaflets large and often borne on leaflet stalks.

Flower: white and freely formed; anthers pale yellow; buds dark.

Kerr's Pink is immune from wart disease and very resistant to blight, but it is susceptible to blackleg and leaf roll. It is a very heavy cropper of excellent eating quality and is

probably the best maincrop variety at the present time. It keeps exceptionally well. It is rather prone to develop second growth in a wet season and its late ripening is a disadvantage.

King Edward VII. — Tuber: kidney (oval to pear-shaped); skin white, more or less splashed with pink; characteristically smooth on surface; eyes shallow; flesh white; sprouts pink.

Foliage: haulm erect, tall, branching, tops crowded; stems with a pink tinge; leaves dark green and glossy; leaflets with waved margins, the younger leaflets on top being very small, narrow, numerous and twisted forward, the last pair fitting round the terminal.

Flower: red-purple, but seldom formed; buds pink; flower stalks short.

The variety is an early maincrop; it is not immune from wart disease. Because of its excellent eating quality and its suitability for the chip trade it is in great demand in many markets and commands a higher price than most other sorts. It is very susceptible to blight and its tender skin makes it readily attacked by grubs and wireworms. It does not respond well to maximum dressings of manure and it should not be planted in very wide drills.

Arran Chief.—Tuber: round (somewhat flat), skin white, with usually a purple spot at the heel during the growing season; eyes medium; flesh white; runners showing a blue-purple coloration; sprouts blue.

Foliage: haulm upright and tall, stem mottled blue-purple, stem wing distinctly waved; leaf moderately open, dull and rigid; leaflets medium to dark green, wrinkled; margins waved; terminal leaflet not drooping.

Flower: white, with green tips, infrequent; anthers malformed and pale; buds distinctly pale green, becoming slightly darker towards maturity and borne on short stalks.

This variety is extremely susceptible to wart disease and mosaic. It is a very good cropper and its tubers, if somewhat rough, are of excellent eating quality. It keeps well, and for a long period it was the most widely grown maincrop.

Golden Wonder.—Tuber: kidney (pear-shaped); skin russet; eyes shallow, saucer-shaped, with raised eyebrows; flesh white to lemon colour; sprouts blue; scale leaves sometimes blue.

Foliage: tall, vigorous, very upright, consisting of a few stout stems, tinged blue-purple near the base; leaflets medium green and markedly wrinkled.

Flower: purple, distinctly white-tipped and freely formed; bases of flower buds green.

The variety is a late maincrop. It is immune from wart disease and resistant to blight but it is very susceptible to mosaic. Although the yield is usually relatively small, quite a good crop can be obtained by sprouting the seed and cultivating the crop on rich land. The eating quality is superlative and for this reason the potatoes always command an extra high price. The keeping quality is excellent. Langworthy differs from Golden Wonder only in that it has a white skin.

Majestic.—Tuber: kidney (pear-shaped to long oval); skin white; eyes shallow; flesh white; sprouts faint pink; second growth takes the form of cracking.

Foliage: haulm of medium height, spreading; less rigid than that of British Queen. Leaf and leaflets flat, open and smooth, ashy green; midribs of young leaves with a pink tinge; leaflets pointed.

Flower: creamy white, profuse. Berries occur freely. Buds pink.

This variety is immune from wart disease but is susceptible to leaf roll and mosaic. It is an early maincrop and is notable because of its heavy cropping capacity. On good land the tubers may be large and coarse; the eating quality is poor.

Field-Marshal.—Tuber: oval; skin russet; eyes shallow and on the point of the tuber; flesh white; sprouts faint pink.

Foliage: haulm spreading, of medium height to tall; stems branching, tinged pink towards maturity; leaf long, spreading, lower leaves conspicuous, midrib of younger leaves

pink tinged at its base and at the bases of the leaflet stalks; leaflet light to medium green, large and dull, end pair markedly overlap the terminal.

Flower: light red-purple, gradually lightening in shade towards the tip, but not distinctly white tipped; blooms freely and for a long period; flower stalks fairly long and thick; buds dark.

The variety is a late maincrop and is not immune from wart disease. It is very susceptible to infection with blight. It is a good cropper and of very good eating quality.

Up-to-Date.—This variety resembles Field-Marshal in every respect except that its skin is white.

Selection of "Seed."—As mentioned above, the older sorts of potatoes wear out and have to be replaced by new and more vigorous varieties, but it is also found that in many localities the yield of a given variety falls off when the farmer propagates the crop for a number of years from his home grown seed. If, however, he buys in seed of the same variety from a suitable district his yield can be maintained, or considerably improved. As a rule the best seed for a typical lowland potato farm is obtained from a northern and high-lying district. Some of the largest potato growers in Lincolnshire and elsewhere obtain all the seed they require from Scotland or Ireland each year, while in other districts it is profitable to buy in fresh seed every second year.

The following table shows the average difference in the yields of twelve varieties grown at the Midland Agricultural College in the seasons 1916 and 1917 from Scotch, once grown, and twice grown seed:—

	Ware.	Seed.	Small.	Total.
	Tons.	Tons.	Tons.	Tons.
Scotch seed . .	10·05	1·97	0·57	12·59
Once grown seed .	6·25	1·16	0·51	7·92
Twice grown seed .	3·45	1·32	0·53	5·30

The main reason why Scotch seed produces such remarkable results is that in cool, upland, and northern districts the climate is not nearly so favourable for the leaf-sucking insects that spread constitutional diseases from affected to unaffected plants, and the seed may be relied upon as being relatively healthy.

Quite apart from any question of disease, however, it has been shown that seed of the same variety, but grown under different soil and climatic conditions, may produce very different yields when planted side by side. Seed produced in an elevated and late district, or from a crop that has had little artificial manuring, is more vigorous than seed grown in a low-lying warm locality or from plants that have been liberally treated with fertilisers. The best soils for the production of seed are those of a peaty nature while the poorest are light and early sands. The heating of potatoes in a pit or during storage may impair the vigour of otherwise good seed.

In northern and elevated districts, where there are few disease-spreading insects, it is possible to maintain the vigour of a potato stock by rogueing out any plants which show signs of constitutional disease. But where stocks are badly affected it is generally more profitable to purchase a small amount of really first class stock seed and to propagate it away from other varieties—say in the middle of a turnip field—so that it will not be readily contaminated. The tubers should be set close together in narrow drills so that a large number of small potatoes may be obtained as seed for the selling crop in the following year.

On all farms where there is a sale for seed potatoes, the crops should be rogued during the growing period so that the produce may be certified with regard to purity.

The size of the seed is a matter of considerable importance, not only with regard to economy in planting but also with a view to the size and number of the tubers that develop in the crop. Before potatoes are marketed it is customary to sort the crop into three grades—namely, ware, which is sold for culinary purposes; seed, which is reserved for planting; and

"chats," which are usually fed along with damaged tubers to stock. The ware is removed from the rest by passing the tubers over a $1\frac{5}{8}$, $1\frac{3}{4}$, $1\frac{7}{8}$, or 2-inch riddle, and another riddle of about $1\frac{1}{4}$-inch mesh is used to remove the chats from the seed. It is obvious that the larger the mesh of the first riddle the greater will be the proportion of seed-sized tubers and the smaller the amount of ware. Farmers who have no market for seed should therefore select a seed riddle having a small mesh, so that they may secure a large part of their crop in the form of a marketable grade. Growers who can obtain a better price for their seed than for their ware naturally endeavour to sell as much of their crop as possible for seed purposes, and they use a first riddle with as large a mesh as the buyers will tolerate. On the other hand, those who purchase the seed can make a given tonnage plant a much larger area when the tubers are small, and they therefore endeavour to obtain seed that has passed through a riddle with a relatively small mesh. In practice the size of the dressing riddle is therefore determined by the relationship between supply and demand. In some rare cases a new and valuable variety can be sold for seed purposes "as grown." Normally, about 16 cwt. of seed is required to plant an acre, but much more is needed when the seed contains numerous tubers of fairly large size. Experiments have shown that, assuming Scotch seed to cost in England twice the price obtained for the produce, the most economical size of set is one weighing about 2 oz.

What effect has the size of the set on the number of tubers produced by the plant? Large sets tend to produce several stems and a large number of tubers which, under ordinary conditions of spacing, cannot grow to any great size owing to the competition of neighbouring plants. Consequently crops grown from large tubers contain an unduly large proportion of seed and chat-sized potatoes. On the other hand, when small sets or cut seed are planted a limited number of stems is produced and the young tubers tend to be few in numbers but large in size, thus yielding a crop in which ware-sized potatoes predominate. There are

large potato-growing districts in Lancashire where there is no good sale for small potatoes but a great demand for ware to supply the industrial population, and to meet this demand the growers sprout full sized potatoes, cut them to one or two eyes for planting, and in this way obtain the sort of crop that is required.

With regard to the yield per acre, large potatoes on the whole produce a heavier crop than small: this is due to the extra food content of the large sets enabling the plants to attain a better development. But with very large sets the cost of the extra weight of seed required for planting may not be met by the improvement in yield. Where seed is scarce or of high value, chats may be used for planting. It is generally believed that the ultimate result of growing potatoes year after year from the smallest tubers will be the degeneration of the stock and a decline in yield; but recent evidence has been brought forward to show that this is not necessarily so.

It is found that when potatoes are cut they can be immediately planted with safety, whereas if the cut sets are stored for a time the crop they produce is liable to reveal blanks, and the yield is diminished; but if their newly cut surfaces are allowed to heal in a fairly warm and not too dry atmosphere, the risk of decay is greatly reduced. Some varieties, however, are noted bad growers when propagated from cut seed and should never be planted in this condition. Cut potatoes, if they are to be stored for a considerable time, should be spread out in a thin layer because, if they are bagged or piled up, they are apt to heat, and heated seed, either cut or uncut, will produce an inferior yield.

Boxing Potatoes.—For a long time it has been common custom among gardeners to sprout their seed potatoes in trays before planting for the early market. Within the last two or three decades, however, the practice has extended to field-grown potatoes, not only in the case of early varieties—although for these it is indispensable—but also for maincrops.

The advantages of sprouting potato seed are numerous, but probably the most important is the increase in yield

obtained from sprouted over unsprouted sets where variety, manuring, time of planting, etc., are the same. This increased yield may be as much as 2 tons per acre and in all cases is very considerable; it is doubtless brought about in part by the longer period of growth, as sprouted plants are through the ground from a fortnight to three weeks before the others; but it is probably also connected with the fact that the whole energy of the set is preserved when it is boxed, whereas if pitted it may waste a good deal of its substance in producing a long weak shoot which breaks off in the subsequent handling. Sprouting also allows the crop to be planted late in a bad year and lifted early in a late district.

Carefully boxed potatoes keep better than sets that are allowed to remain in the clamp until setting time; the skins of the former become tough and rubbery, especially if they are exposed to a preliminary greening, and they suffer little from shrinkage. Another advantage of boxing is that the seed can be gone over from time to time and any tubers that fail to produce buds or show signs of disease can be removed; also the colour of the sprouts may indicate the presence of rogues and these can be separated.

Boxing is carried out by placing the seed in shallow boxes or trays—immediately after lifting if possible, but even in winter as late as a month or two before planting. Different sizes of boxes are used, the larger being less costly per ton of seed but rather difficult to handle at planting time; the small sizes have cross spars and can be conveniently carried by a single worker. When the boxes have been filled they must be stored in a suitable building where they will receive plenty of light, and where there is no risk of the temperature falling below freezing point. In Lincolnshire many growers have erected large glass-houses, filled with heating apparatus, in which they sprout the whole of their seed. Of course it is unnecessary, and in fact inadvisable, to keep the buildings at a high temperature; but during periods of severe cold and threatened frost the heat should be turned on to avoid any risk of the potatoes being damaged. As a matter of

fact potatoes withstand about four degrees of frost without injury, but more than this causes a portion of the starch to be converted into sugar and results in serious damage. The boxes are piled up one upon another so as to economise space, but they must be rearranged from time to time so that all the sets are exposed to light. When potatoes are sprouted in the dark the shoots are long, thin, and weak, and when handling takes place before planting the stems tend to be broken off, thus diminishing the food reserves of the tuber and causing a considerable loss of time before new shoots develop. Nevertheless, sets that have long shoots do well if they are carefully handled. There is a wrong belief that long sprouts should be broken off; it has been demonstrated that this leads to a diminution of the crop. The most desirable sprouts, which develop when the tubers are exposed to plenty of light, are short—not exceeding 2 in.—strong, and well greened; they are not easily broken and develop rapidly when the sets are planted.

When circumstances permit, beneficial results are got by exposing seed to direct sunlight before it is boxed. The small grower would do well to raise a portion of his tubers before they are quite mature, green them to harden them off, and box them for the next year's setting.

Cultivation of Potatoes.

Soil and Climate.—The most suitable soil for potatoes is a light loam or alluvium, but the crop does well on black-top or peaty land. The potato is one of the few farm plants that tolerate the absence of lime or an acid condition of soil; indeed liming shortly before planting is injurious rather than beneficial. When grown on peaty land potatoes produce a heavy yield; but the quality is somewhat inferior, and on the English market they command a price below the average. The finest quality is obtained from the loams of the Old Red Sandstone formation, which produce potatoes that do not darken after boiling, but remain pure white. Potatoes do particularly badly on heavy soils and under

wet conditions, and farms situated on such land never produce the crop at a profit.

As potatoes are cultivated on a field and garden scale from the dry east coast to the heavy rainfall districts of Ireland, it may be concluded that they thrive under our whole range of climatic conditions; but in very wet seasons the liability to disease is much accentuated, and there is great difficulty in securing the crop from the water-sodden soil. Warm, light-land districts bordering on the sea coasts are ideal for the production of early varieties, because the sets can be planted as early as February without fear of destruction by late frosts. These soils, too, by reason of their powers of withstanding enormous manurings without "sickening" or suffering in texture, are well suited to produce the heaviest crops. The best potato soil is one that admits of liberal manuring; it does not require to be naturally rich. Many areas devoted to the cultivation of early potatoes have a northern or western exposure, while land lying to the south or east in the same districts is unsuitable. This is because late frosts are inevitable, but where the plants are gradually thawed, as when exposed to the north, they are not injured. On the other hand, where rapid thaw is produced by the direct insolation, the leaves are stricken to the ground.

Place in Rotation.—Potatoes are usually taken between two straw crops so that the rotation receives a maximum of benefit from the cleaning of the land. On the best potato soils, however, no other crop is grown, and potatoes are cultivated year after year without failure. The early sorts may be followed by a quick growing catch crop of mustard or rape, but no other crop is actually sold off the land. Potatoes do exceptionally well after old grass, and they form, if the land has been rendered very rich through a long period of grazing with heavily fed stock, a safer crop than oats or wheat. The decaying sod provides the humus that is so necessary for high yields, and on a system of farming where the dung supply is somewhat short, it is always advisable to grow a portion of the potato crop in this place in the rotation.

Preparation and Planting.—As the potato crop practically always receives a dressing of dung, the management of the cultivations will depend very largely on the time of the year when the manure is applied. Under average farm conditions it is often most economical to apply the dung during the winter and plough it in as soon as possible. When this has been done and the ploughing completed, the land, as early in spring as it becomes workable, is worked into a deep tilth—not necessarily fine—by cultivating and harrowing. It is then drawn into ridges for planting by means of a double mould board plough or a special machine that is capable of forming two or three ridges at a time, though a swing plough can also be used. When the dung is applied in spring it is spread between the ridges, and the potato seed is placed directly on the manure. This method of application gives very good results, as the manure decomposes immediately round the plant roots; but the carting and spreading are slow and laborious at a time of the year when much other work has to be performed.

When the crop is taken after a tough old lea, the preparation is frequently much more difficult, as the sods take a long time to decompose and tend to work to the surface during the cultivating and ridging operations. Under such circumstances the disc harrow is a valuable implement. In deep soils this difficulty is overcome by double ploughing. For this purpose two ploughs are required: the first skims off the whole of the sod and turns it into the bottom of the furrow made by the second plough, which follows the first, making a deep furrow and covering the turf with an 8 or 9-in. slice. Many soils are too shallow to allow of such deep cultivation, but can be worked according to the same principle, though on a smaller scale, by fitting each plough with an efficient skim coulter to bury the turf.

The time of planting depends upon the district and the variety that is being grown, the risk of early planting being in proportion to the liability of the district to late frosts. In the earliest localities, where frosts are practically absent,

planting commences in February. April, however, is the usual month for setting the maincrops. It is a matter of prime importance that the land should be sufficiently dry and in good working order at planting time, as a crop set in cold, wet soil seldom develops satisfactorily.

The distance between the potato drills should be varied according to local circumstances and the requirements of the crop. When potatoes are grown for the early market, and their growing period is too short to allow them to benefit by abundant space, it is usual to have the drills comparatively close together (about 22 in.) and to set the tubers about a foot apart. Maincrop potatoes, however, because of their long growing period, require more room to develop, and it is usual to place them in 26 or 27 in. drills and to set them at intervals of 15 in. Nevertheless, where the land is very rich and the potatoes tend to attain an excessive size, or where it is desired to obtain a large proportion of seed, the tubers may be set at lesser intervals.

The depth of the drills is varied according to whether the land is dunged on the flat or in the drill, more depth being required in the latter case. It is advisable that early planted potatoes, or potatoes set in districts that are liable to late frosts, should be deeply set so that they receive adequate protection during the early stages of growth; they can be brought nearer the surface by harrowing down the ridges when the danger of frost is past.

Most potatoes are set by hand, but there are now many satisfactory potato-planting machines which, if considerable areas are grown, soon repay their cost in economy of labour. While most of the mechanical planters do good work with ordinary seed, they are unsuitable for planting sprouted potatoes, as they break off the majority of the shoots. It is possible, however, to obtain a planter that can take both sprouted and cut seed, but extra hands are required to sit on the implement and drop the sets, one at a time, into the travelling cups: they are nevertheless more speedy and economical than planting by hand. These machines can, of course, be set to drop the tubers at any desired intervals.

The sets are covered by splitting the drills down the middle. During the performance of this operation a certain amount of damage is done to the tubers by the tramping of the horses, and, although most farmers take this risk, it is worthy of note that it is customary in certain districts to train the near side horse to walk on the top of the ridge so that none of the tubers is displaced or injured.

Manuring.—The basis of potato manuring is a heavy dressing of good farmyard manure, and the only occasions when this may be neglected are when the crop is taken after a rich old pasture, where seaweed is available, or where green manuring has been carried out. The amount of dung applied varies from 12 to 20 tons per acre; but if the land is rich the smaller quantity should be applied, as 20 tons tend to produce rank and luxuriant foliage and a reduced yield. Best results are usually got by applying a limited amount of dung supplemented by artificials. No plant is more dependent on potash supply than the potato, and even where the soil is of good body, and potash produces no return when applied to cereals, a liberal dressing should be given. Sulphate of potash has for a long time been the most popular potassic fertiliser for potatoes, and in certain cases it gives, unit for unit, better results than any other form; in other cases it seems that muriate is equally beneficial. If the only available form, however, is kainit or sylvinite, it should be applied very early so that it may be well washed by the winter rains.

A suitable mixture for second early and maincrop potatoes consists of 2 parts sulphate of ammonia, 3 to 4 parts superphosphate, and 1 to 2 parts sulphate or muriate of potash. The smaller proportion of phosphates should be applied on land where phosphates are used liberally for the other crops in the rotation and where there is therefore a fair reserve in the soil, while the larger proportion should be employed where the soil has received little of these fertilisers for a number of years. With regard to the potash, the smaller proportion may be sufficient on soil that has plenty of body and on land that has been generously dunged. The

larger proportion will be needed on lighter soils or where little farm manure has been applied.

The following quantities of the mixture are likely to yield a profitable return when used in conjunction with moderate dressings of dung. On poor potato land that does not normally yield more than 6 to 7 tons of potatoes per acre, apply 5 cwt. per acre. On land that may yield 8 to 10 tons, apply 7 to 8 cwt. per acre. On good land that can yield 11 to 13 tons, apply 10 cwt. per acre. Where no farm manure has been employed, the standard dressings may be increased to some extent, but not more than about 12 cwt. of artificial fertiliser should be applied per acre without a preliminary trial on a small scale.

Early potatoes are manured very liberally in order to force them to bulk and mature early. In the early district of Ayrshire it is common to apply, in addition to as much organic manure as is available, mixed artificials at the rate of 13 to 15 cwt. per acre. The general belief is that the mixture should be rich in nitrogen and phosphates but relatively poor in potash, and 15 cwt. of a common early potato compound would represent nitrogen equivalent to over 6 cwt. of sulphate of ammonia, about 1 cwt. of muriate of potash, and the remainder phosphates of different grades.

In many coastal districts seaweed is used for potatoes and produces extraordinarily good results. Ton for ton it is slightly better than dung, its superiority probably being due to its higher potash content.

After-Cultivation. — Probably no crop receives more cultivation than the potato, and from a few weeks after the sets are covered over until the plants meet across the drills the land is subjected to a long series of hoeings and draggings. These operations aerate the soil and facilitate bacterial action; they conserve moisture, kill off the weeds, and leave the crop in a suitable condition for lifting. The sequence of operations varies greatly, but as a rule the drills are harrowed down two or three weeks after planting; they are then horse-hoed if necessary, and earthed up with a one-horse plough; this is followed by a series of horse-

hoeings and a hand-hoeing, and the ridges are finally earthed up with a two-horse plough. Wherever the soil is hard below, a deep grubbing with two horses should be done early, before the roots of the plants are widely spread. Nothing is more important than to obtain a deep mellow tilth. After the tops are so big that horse work has to cease, hand pulling of weeds may be continued. If part of the crop is intended for seed, it is necessary to go through the field when the plants are in flower and to remove all "rogues" so that the purity of the variety can be guaranteed.

Spraying.—Perhaps the greatest loss sustained by potato growers is due to the ravages of potato disease or "Blight." It has been found that this pest can be checked to a considerable extent by spraying the crop with a suitable fungicide. Not only do the chemicals stop the growth of the fungus, but their application tends to prolong the growing period of the crop, and the longer assimilating season results in an increased yield. Potatoes grown in the south and west suffer more from the disease than those cultivated in the drier eastern counties, but in a wet season the ravages of blight are most severe and the whole country suffers. What is the attitude towards spraying taken up by the large and up-to-date growers of potatoes? In the large potato-growing districts of Lincolnshire, to take one instance, practically all the growers provided themselves with spraying tackle and gave the treatment a fair trial; but many do not spray now, and prefer to make the best of a bad year by growing varieties that are somewhat resistant to blight. These farmers proved that while spraying was profitable in a "disease year," the majority of Lincolnshire summers were so dry, and disease so little prevalent, that the outlay gave no useful return. Taken on the whole, the saving due to spraying in a wet season was not sufficient to cover the cost of the operations in the other years. It has, of course, been proved that in other and wetter districts spraying is attended with profitable results, and an increase of several tons per acre over unsprayed crops is not unusual.

To prepare Bordeaux Mixture for spraying, 4 lb. of copper sulphate should be dissolved in 35 gallons of water in a wooden barrel, and 2 lb. of freshly-burned quicklime should be slowly slaked and made up to 5 gallons of "cream." The lime should then be poured slowly through a sieve into the copper solution, which should be kept thoroughly stirred, and a fine flocculent precipitate of copper hydroxide, which is the active ingredient of the fungicide, is produced. It is important that no free copper sulphate be left in solution as it is poisonous and injures the crop. To find out if sufficient lime has been added to cause a complete precipitation, introduce a polished knife blade: it will become coated with a thin film of copper if any of the soluble salt is present.

Burgundy Mixture is commonly used where no good lime is obtainable. This is prepared by dissolving 4 lb. of copper sulphate in 35 gallons of water, and 5 lb. of washing soda in 5 gallons of water, and mixing the solutions.

About 100 gallons are required to spray an acre. The time of spraying is very important, and as the time varies in different districts it is impossible to lay down any hard and fast rule, but, on the whole, the first spraying in the southern counties should take place in the middle of June, the middle of July in the midlands, and the last week of July in the northern counties. The best results are got when two sprayings are given, the second application being a fortnight to three weeks after the first; but in some of the wetter localities it is profitable to give three dressings, especially when the weather is damp and misty. The spraying nozzles must be kept free from sediment so that the finest possible spray is obtained, and, as far as is practicable, both sides of the leaves should be coated.

Dry spraying or dusting the foliage with a prepared powder containing copper salts is a much less laborious process than wet spraying, and gives fairly satisfactory results.

Lifting Potatoes.—Maincrop potatoes are lifted when the foliage has died off and the growing season has come to an end. At this time, too, the skins of the tubers are

thickened by a deposit of corky tissue, and they suffer much less through mechanical injury than when they are lifted early in the season. The time of lifting varies according to the season and the locality, but most crops are secured between the middle of September and the first week in November. The potatoes are dug by means of a potato plough or by a digging machine. The plough is probably less injurious to the crop, but it does not scatter the tubers well, and many are left covered by soil; the digger, on the other hand, may slice a few tubers but it greatly facilitates gathering—an operation which at best is laborious and expensive. In many seasons in late districts the crop is raised long before the haulms have died down. In such cases it is necessary to scythe down the green parts and to remove them before the digger can be put to work. One gatherer will work at about one-twentieth of the rate of the digging machine when lifting an average crop, and twenty gatherers will therefore be necessary to keep pace with a machine digging in both directions; but more workers will be required for a heavy crop.

The lifting of early potatoes commences in June, long before the tubers are hardened or the foliage has ceased to function, and for this reason it is profitable to raise the crop by hand, using a graip or four-pronged fork. When this is done two gatherers work with each digger. The potatoes are then graded and packed into barrels immediately, and sent straight from the field to the market. Owing to the great cost it only pays to hand dig first early crops that command a high price.

After the preliminary gathering has been completed the field is given a good harrowing to bring to the surface any tubers that have been missed or overlaid by soil; they are then collected and removed in the usual way.

Storing Potatoes.—The crop is secured as it is lifted by putting it into a "pit" or "clamp." The principles of clamping are the same throughout the country, the construction being designed to protect the potatoes from frost and rain, and at the same time to allow a certain amount

of ventilation. The clamp, which is made as long as is necessary, and generally from 4 to 6 ft. wide, is commenced by excavating the soil to the depth of a few inches, or simply levelling the surface of a piece of land that has a good natural drainage and is adjacent to a cart track. The tubers keep best in narrow pits, but these are more expensive in straw and in labour. The potatoes are tipped on to the pit bottom, dressed up as high as possible, and immediately covered with good wheat or rye straw. (The softer straws are not suitable as they decay in damp weather.) The straw is then covered to within a foot of the top of the clamp with about 2 in. of soil, so that there is ample ventilation to allow the heat, produced by fermentation and respiration, to escape. The heating due to these causes is quite normal, but in the presence of sufficient moisture and the absence of ventilation the bacteria may become so active that the temperature rushes up, the potatoes are literally cooked, and the clamp collapses. After a few weeks, however, when the free moisture in the clamp has decreased, and the respiration of the tubers has become less active, the clamp should be earthed up a second time so that there is a covering of about 6 or 8 in. of soil to protect the contents from frost; but even at this stage bunches of straw should be allowed to protrude at intervals along the apex to allow a certain amount of aeration.

In order that the crop may keep well it is important that the tubers be clamped in as dry a state as possible; moisture encourages bacterial and mould growth which produce rapid deterioration. It is also desirable to exclude all diseased tubers. Harrowings, which consist largely of inferior and damaged potatoes, should be pitted separately and used up as early as possible.

An inevitable loss goes on while potatoes are in store due to respiration and disease, and the condition of the tubers should be inspected every two or three weeks, so that they can be sold and despatched at once if they are found to be deteriorating rapidly.

Marketing potatoes consists of grading them as outlined

in a previous section, picking them over to remove diseased or broken tubers, and either weighing and bagging them, or carting them in bulk to wharf or railway wagon.

Yield.—An average crop of potatoes will yield 6 to 7 tons per acre, but 16 tons and over may be got in good districts in favourable seasons. When ordinary riddles are used for dressing, about 7 and 25 per cent. of the crop will be sorted into chats and seed respectively.

Potato Diseases.

The following is a broad grouping of the common potato diseases together with notes according to their importance :—

A. Diseases affecting the tuber only and that superficially :—

(*a*) **Silver Scurf** (*Spondylocladium atrovirens*). — This disease is not important as little or no damage is caused to the affected tubers.

(*b*) **Common Scab** (*Actinomyces*).—The scabbing gives the potatoes a very unsightly appearance but has little affect on the yield. The attacks are worst on sharp soils and after liming, because these conditions promote a rapid loss of humus and cause the fungus, which can live saprophytically on decaying organic matter, to pursue a parasitic existence. It has been shown on a small scale that the placing of grass cuttings round the sets at planting time will give the fungus material to work on and prevent the developing tubers from being attacked.

(*c*) **Corky Scab** (*Spongospora subterranea*).—This form of scab may be indistinguishable from common scab and in its mild form does practically no harm. Where potatoes are repeatedly grown on the same ground, however, the attack may be so severe as to form a canker and render the affected tubers useless.

(*d*) **Skin Spot** (*Oospora pustulans*).—This disease develops on the tubers during storage and does little harm unless it spreads to the eyes and prevents seed from sprouting.

(*e*) **Black Scurf** (*Corticium solani*).—This is seen in the

form of small black tar-like lumps on the skin of the potato. The lumps can be scraped off without apparent damage to the tuber. The fungus may attack the sprouts of potato sets after they have been planted and thereby cause blanks in the crop.

B. Diseases which cause the tuber to rot:—

(*a*) **Sprain.**—The flesh of affected tubers contains brownish regions. The affection is believed to be caused by bacteria; it does not unfit the tubers for seed purposes but seriously reduces the eating quality of ware; it occurs chiefly on sandy soils deficient in humus.

(*b*) **Dry Rot** (*Fusarium cæruleum*).—This fungus does most damage to the seed of early varieties during the storage period. The affected tubers shrivel and become dry and wood-like. The disease is most likely to spread when the potatoes have been bruised through careless handling.

(*c*) **Pink Rot** (*Phytophthora erythroseptica*).—This disease is most common in the west of Ireland and can be very serious where potatoes are grown year after year on the same land. The rot commences when the potatoes are still in the ground and continues until they are completely decomposed. The disease gets its name from the pink coloration which develops on the freshly cut surfaces of affected tubers. As the fungus remains in the soil the remedy is to adopt a proper rotation.

Wart Disease (*Synchytrium endobioticum*).—This disease has come into prominence in recent years because of the increasing area of the land affected, the loss occasioned by its ravages, and the methods established for its suppression. The fungus produces wart-like excrescences at the eyes of the tubers and on the basal shoots of the plants. The out-growths are at first white but later become dark brown in colour, and vary from the size of a pea to a warty mass that envelops the whole tuber. The disease is propagated from year to year by spores that are liberated in the soil, and as the organism is capable of existing in a latent state for many years, it is practically ineradicable.

Fortunately the existence of immune varieties makes the growing of healthy crops on badly infected soil still possible, but if any other kinds are cultivated there is no possibility of starving out the fungus and of getting the land clean. For this reason the Ministry of Agriculture has found it necessary to define certain disease areas in which only varieties that have been proved immune may be planted. It is also necessary to prove that the purchased seed is true to type and contains no susceptible rogues; and growing crops destined for the seed trade must be inspected and passed for purity by the Ministry's officials before a certificate is granted entitling their sale in a disease area.

C. Diseases which attack the foliage but not the tubers:—

(*a*) **Stalk Disease** (*Sclerotinia sclerotiorum*). — This disease is most common in the west of Ireland, particularly where there is no proper rotation. The fungus passes the winter in the ground and the spores are liberated in spring. The affected foliage falls over and decays, thereby cutting short the growing period and reducing the yield. The remedy is to avoid growing potatoes on the affected ground for at least three years. Late planting sometimes gives good results.

(*b*) **Botrytis Disease** (*Botrytis cinerea*).—As a rule this fungus attacks and destroys a few of the stems and leaves, and only in severe cases does the damage extend to the whole of the foliage. The yield of affected plants is of course reduced. Varieties that are resistant to Blight usually resist Botrytis.

D. Diseases which attack the whole plant and destroy both haulms and tubers:—

(*a*) **Blackleg** (*Bacillus atrosepticus*).—By the middle of June affected plants may be detected by their yellowish colour. The base of the stem is blackened and decayed and the stalks are easily pulled away. Later in the season the young tubers become more or less affected, especially at the heel end. Decay continues and spreads during storage, and if slightly diseased tubers are planted they give rise to diseased plants. Blackleg may be kept in check by

planting only healthy seed and it may pay to dig and destroy affected plants. It has been observed that the following varieties are rather susceptible to the disease: Kerr's Pink, British Queen, Arran Consul, Great Scot, King Edward VII., Majestic, Rhoderick Dhu, Duke of York, Epicure, and Eclipse.

Potato Disease or "Blight" (*Phytophthora infestans*).—This is the worst scourge of the potato crop; not only does the fungus attack the foliage of the plant and cause it to decay and die off prematurely, but the disease finds its way through the soil to the tubers and the potatoes become dark coloured, soft, and decayed. Not only is the yield greatly reduced, but many affected potatoes have to be discarded as soon as they are lifted. Spores of the fungus, present on seemingly unaffected tubers at lifting time, also cause the potatoes to become diseased during the period of storage, and in an extreme case the contents of the clamp may be reduced to a soft mass of putrefaction.

The outward manifestation of the disease on growing potatoes is a browning and dying-off of a portion of the leaf tissue, and if the under-surface of an affected lamina is examined the presence of the spore-bearing conidia can be observed round the dead tissue. The affection takes place in July and August, and is most severe during periods of warm, damp, and misty weather, which facilitates the germination of the reproductive spores on healthy plants and thus propagates the disease rapidly.

As mentioned above the only known treatment for an affected crop is to treat the plants with a fungicidal spray. The disease can be prevented to some extent, however, by a very careful selection of seed, taking care to exclude all sets that exhibit the minutest trace of infection: this inspection, of course, can best be performed when the seed is sprouting in boxes. Treatment and inspection, however, are costly, and the best insurance against attack is to cultivate varieties of known disease-resisting quality. Unfortunately no variety is absolutely immune to Phytophthora, but many sorts are highly resistant, and doubtless the

elimination of the disease in the future is in the hands of the plant breeders, for with further experience it should be possible to bring out a variety that is totally immune. Thorough earthing up of the crop will help to keep the spores from being washed down from the foliage to the tubers.

Murphy's experiments in Ireland have demonstrated that potatoes which are dug while the stalks are blighted, but still living, are practically sure to develop blight during storage, and it was concluded that a large proportion of such tubers became infected during digging operations from contact with blighted foliage or contaminated surface soil. The inference from these experiments is that either the crop should be lifted before it is seriously blighted or left for about a fortnight after the haulms are dead, when the spores will have lost their virulence. The former course is the better and should be adopted when practicable, as in the case of early varieties. The latter course involves the risk that in spite of the precaution the infection may reach the tubers through the soil; but this risk may not be serious where the potatoes are well covered with close textured earth.

The problem of disposing of a highly infected crop has to be considered by the practical man. It is dangerous to feed the tubers to stock, because the infection is carried to the next crop through the manure. The best plan is to dispose of the seeds and chats together as "pig potatoes" to a farmer who does not go in for potato-growing. The picked ware can of course be sold in the usual way, but it is advisable to sell it immediately, even if a lower price has to be accepted, because if it remains in store the disease develops so rapidly on the affected tubers that in a few months' time little or no marketable produce may be left.

The tubers of the following varieties are relatively resistant to infection with blight:—Arran Consul, Evergood, Rhoderick Dhu, President, Lochar, Irish Queen, Kerr's Pink, Champion, Irish Chieftain, Langworthy, Golden Wonder, and Arran Victory.

The tubers of the following varieties are susceptible to infection with blight: — All common first-early varieties, British Queen, Katie Glover, Arran Comrade, Catriona, King Edward VII., Up-to-Date, Field Marshal, Sutton's Abundance, King George V., and Great Scot.

E. Disease affecting the whole plant but not destroying the tubers:—

Verticillium Wilt (*Verticillium albo-atrum*).—This fungus more or less blocks up the water channels in the plant thereby causing the leaves to become limp or to wilt. The haulms die prematurely and the development of the tubers is checked. The fungus passes into the young potatoes through the underground stems, and if such potatoes are planted they will give rise to a diseased crop. The remedy is to buy in healthy seed.

F. Diseases which affect the whole plant but do not cause decay:—

Degeneration Diseases.—It was formerly believed that potato stocks underwent a natural process of degeneration, and that no matter how good a variety might be for a few years it would ultimately have to be discarded owing to old age. It is now known, however, that the deterioration is brought about by virus diseases. Affected plants assume a dwarfed and mottled, curled or crinkled appearance, and their yield is greatly reduced; they also ripen prematurely and the disease is perpetuated through their tubers. The sap of a degenerated plant contains the disease virus and the affection is spread to healthy potatoes by means of greenfly. As greenfly are most numerous in warm, early and sheltered districts, potato stocks degenerate most rapidly in these localities. On the other hand, potatoes grown in cool upland and late districts remain healthy almost indefinitely as they run little or no risks of inoculation. As mentioned in an earlier section it is profitable for southern growers to purchase their seed from a locality which contains healthy stocks. Growers in districts where greenfly are few can keep the diseases in check by rogueing out degenerate plants.

Leaf roll is one of the best known and most widely spread of the degeneration diseases. A typically affected plant is reduced in size and has stiff crisp lower leaves which roll upwards and inwards. British Queen, Katie Glover, Majestic, Arran Consul, Kerr's Pink, Duke of York, and King George V. all appear to be relatively susceptible to the effects of infection with leaf roll.

Mosaic diseases, including ordinary mosaic, crinkle, etc., are even more common than leaf roll. In these diseases the dwarfed plants exhibit a wrinkling and puckering of the leaves together with a pale coloration and a mottling of the foliage. The following varieties have been observed to be relatively susceptible to the effects of infection with mosaic:—Langworthy, Golden Wonder, Arran Chief, Tinwald Perfection, Majestic, Irish Chieftain, Katie Glover, and Immune Ashleaf.

Apart from infection with virus disease, potatoes may develop degenerate forms which have been termed respectively Bolters and Wildings. A Bolter possesses abnormally tall, open, and vigorous foliage and usually has a very free flowering habit; it is late in maturing. A Wilding has an abnormally bushy habit of growth and develops an exceptionally large number of thin branches; it produces a very large number of small tubers. Both the Bolter and Wilding conditions are perpetuated through the tubers.

Insect Pests.

Potatoes are not much parasitised by insects, but are attacked to some extent by the Death's-head Moth and, in other countries, the Colorado Beetle. Leather Jackets and Wireworms are, of course, destructive.

CHAPTER III

THE ROOT CROPS—TURNIPS AND SWEDES

Turnips and swedes are biennial plants belonging to the cruciferous genus *Brassica:* they are termed "roots," but the fleshy portions are in fact enlarged hypocotyls and contain but little true root tissue. Their habit is to store up large quantities of food material in the first year of their growth, and to develop their reproductive parts and to ripen their seed in the second season. The species that do not develop swollen hypocotyls are known as rapes, and are grown for seed production and for soiling or folding.

The turnip is our most widely cultivated root crop, especially in the northern and more humid regions. It is commonly but wrongly believed that the turnip was brought to Britain about the time of the origination of the Norfolk rotation, and that it is therefore a comparatively recent introduction; in reality it was cultivated on a small scale as long ago as Norman times. During the early days of field cultivation turnips were sown broadcast, but about the end of the eighteenth century drilling on ridges began to be common. About thirty years later a new sort, possessing distinct characteristics, was introduced from the continent and called a Swede, after the country of its origin. Turnips and swedes increased rapidly in popularity as soon as the system of drill cultivation had been established, as up to this time the only means of bringing foul land back to a state of cleanliness and fertility was to turn it over to bare fallow. Turnips grown in drills, however, permitted cleaning operations and avoided the waste and expense due to the want of a crop.

Root crops are primarily grown with the object of producing winter food for stock, and differ from potatoes in

being almost universally consumed on the holding, thus conserving the soil fertility. They also, as mentioned above, form a most important cleaning crop, and, indeed, the only cleaning crop in a great many rotations. The food value of turnips is high—not weight for weight with other foods, but in proportion to the dry-matter content. In nature the turnip is not comparable to a roughage like straw or hay because its bulk consists not of indigestible fibre, but of water. The great advantage of roots, of course, is that they are succulent and palatable at a time of the year when no other appetising food is available, and they cause animals to relish the rest of their ration and to eat more in consequence. A large proportion of the turnip crop is eaten off by sheep, and many light-land farmers maintain that without their turnip-fed sheep they could not keep their farms under the plough.

Varieties.—Those sorts of turnips and swedes which produce the highest yield per acre, and at the same time have a high feeding value, are the most valuable. The dry-matter content of different varieties varies very considerably, and the heaviest yielder is not necessarily the most productive of dry matter. In the absence of more precise knowledge, however, it may be assumed that the feeding value of the roots is proportional to their dry matter content. Quality is of great importance, and in the selection of newer and better kinds analyses should be made from time to time to ascertain the composition. Quality is also influenced to some extent by manuring, since by using certain fertilisers it is possible to force the roots to a great size; but the extra weight is mostly water, which is useless for feeding and makes the crop difficult to handle. The following are other points that should be considered in variety selection:—The seedling should grow and develop its root system rapidly, as there is a great danger of the plant becoming dried out before it reaches the rough-leaf stage; there should be a minimum proportion of weight in the tops, which are of little use, and a maximum in the roots; the bulbs should grow well out of the ground to facilitate lifting, and, lastly, the

capacity to resist disease should be high, as, other things being equal, a disease resisting sort will produce a very superior yield.

Turnips and swedes are cross-fertilised plants and even the common varieties show such a marked tendency to variation that it is only by very careful selection of mother-roots that they can be kept reasonably true to type. In actual practice seedsmen may have different ideas as to what represents the best shape, colour, etc., of a given variety, and if they make their selection from the same stock the result will be that a number of different types appear on the market under the same name. In fact this state of affairs has so far made an accurate classification of turnips impossible. Although certain commonly recognised types of swedes and turnips are described below, it should be clearly understood that, for reasons stated above, there are many varieties having characteristics that are not in accordance with the grouping.

Swedes. — These can at once be recognised by their glaucous leaves, which also differ from the rough-looking foliage of the turnip in having no hairs and in arising from a neck, or stumpy stem. The colour of the flesh is yellow. The swede is harder than the turnip, has a better feeding value, and is sweeter to the taste. Swedes require better soil and treatment than is necessary for turnips, and although they do not mature so rapidly, they withstand frost and disease much better, and keep longer. They should not be fed to stock while they are immature, as in this state they are apt to cause digestive disorders, but should be consumed after the ordinary turnips have been used up.

The following types of swedes are commonly recognised:—

1. *Early Purple Tops* are generally the quickest growing, heaviest yielding, though least hardy varieties; they contain on the average about 11½ per cent. dry matter,[1] and are not of much higher feeding value than the best yellow turnips;

[1] The composition of roots is so very largely dependent on soil and climatic conditions that the figures for dry matter contents must be considered as relative only.

they do not keep very well and should be the first swedes to be consumed. Best of All, Magnum Bonum, Early Round, Superlative and Picton belong to this type.

2. *Maincrop Purple Tops* are intermediate in character between the Early Purple Tops and the late hardy varieties possessing a high dry matter content. Varieties of this type are Aberdeenshire Prize, Bangholm, and Springwood.

3. *Bronze Tops* are intermediate in character between the Early Purple Tops and the Green Tops, and contain about 12 per cent. dry matter. They include the following varieties: X.L. All, Caledonian, and Darlington.

4. *Green Tops*, although the slowest of all swedes to mature and the smallest croppers, produce roots containing over 12½ per cent. dry matter, and are the best of all for keeping quality. A variety of this type is Old Kinaldy.

Turnips. — The foliage is pale green, and the lyrate leaves, which are covered with hairs giving them a rough appearance, spring from the top of the "root" in a rosette. Some varieties have elongated bulbs, the greater part of which is above ground level, some are short and globe-shaped, and others are intermediate. They may be white, any shade of green or purple, or mottled; but the colour has no special significance. Turnips have a much shorter growing season than swedes, and, indeed, can be grown as a catch crop after harvest in early districts: this quick maturity allows them to be fed early without endangering the stock; indeed early feeding is necessary as they do not withstand frost nor keep well. Turnips, in relation to the length of their growing season, yield more total weight per acre than swedes, but are inferior in feeding value; they have about 5 per cent. more foliage than swedes, the proportion of root to top being about 5 to 1.

The following are the three principal classes of turnips:—

1. *White Turnips.*—These contain only 7½ to 8 per cent. dry matter, and, although the heaviest croppers, are of the poorest feeding value. They can be grown on the poorest of soil; they are often sown to fill up headlands and fed with their leaves to stock on the grass towards the end of

summer, or they may be broadcast after harvest to form a catch crop; their keeping quality and frost-resisting power are very low. Two well-known varieties of this class are Greystone and White Globe.

2. *Soft Yellows* are intermediate in quality between whites and yellows, and contain 8½ to 9 per cent. dry matter. Fosterton's Hybrid and Early Sheep Fold are of this type.

3. *Hardy Yellow Turnips*, of which the Aberdeen Yellow is the best known, are about as good as swedes in keeping quality and feeding value; they contain 10½ per cent. dry matter, and are very hardy and frost resistant.

Cultivation.

Soil and Climate.—Turnips and swedes are the typical roots of Scotland, Ireland, and the north and west of England; but they are also largely grown on the poor, thin soils of the chalk formations. The crop, like oats, attains its highest perfection in cool, wet climates; when grown under dry conditions the yield is very low. Turnips thrive better than mangels in an absence of sunshine, and their shallow root systems render them liable to be dried out in districts of low rainfall.

The most suitable soils are those of the lighter class, as on heavy land it is difficult to get the required fineness of tilth for the germination of the small seed, and the fine rootlets do not grow so well through the close texture.

Place in Rotation.—In most cases roots form the chief cleaning crop of the rotation, the cleaning operations commencing before seed-time and going on throughout the period of growth. As is to be expected, then, roots are taken between two straw crops, but they cannot easily be taken before early sown wheat as it is difficult to get them off the land in time. The frequency with which turnips recur on the same ground depends largely on the risk of Finger-and-toe, but the interval is rarely less than four years, and may be seven or more in districts where the soil is poor in lime and the disease is more insidious.

Preparation and Sowing.—The soil for turnips receives a more complete and thorough preparation than is the case for any other crop in the rotation. This is possible, because turnips are sown comparatively late and at a time when most of the labour of the farm is freed from the other spring operations, and is necessary, because of the very fine tilth required for germination and growth. The land must also be cleaned of weeds which would compete with the struggling plants in their young stages, and it is usual to drag out and burn as much "twitch" as possible. As in the management of the potato crop, the sequence of operations depends to a great extent on whether the dung is applied in autumn or in spring. When spring dunging is intended the land is ploughed as deeply as possible in autumn to bury the surface weeds, to facilitate aeration and drainage, and to allow it to benefit by the action of frost. In spring the land should be shallow ploughed once, or oftener if possible, each ploughing being followed by a dragging to fetch the weeds to the surface, so that they can be rolled up with the chain harrows, collected, and removed to a compost heap or burned; the fine mould should then be prepared by a series of cultivations, harrowings, and rollings. Two important points should always be borne in mind when preparing turnip land: the first is the danger of over-cultivation, resulting in the drying out of the surface layers and a consequent failure of the seeds to germinate; the second is the importance of seizing every opportunity to gain the required tilth with a minimum of operations, which is best done by taking advantage of every fall of rain to work the clods when they are most easily broken, *i.e.*, when they are in a half-wet, half-dry condition. When the desired tilth has been obtained, the land is ridged as for potatoes, well-rotted muck is spread in the furrows, the artificial manures are broadcast, the ridges are split to cover the manures, and the land is ready for seeding. In the preparation of turnip ridges the ordinary double mould board plough does not give the best results, as it has a pushing action and tends to leave the clods and coarse particles of soil on the tops of the ridges where the seed is to be sown,

and the dry surface layer in the middle of the ridge under the seed. An ordinary swing plough in the hands of a capable workman can do better work by rolling the clods to the bottom, digging up the fine, damp, pulverised soil, and leaving it where it is most required by the delicate seedlings.

In all the typical turnip-growing districts the crop is grown on ridges, which average about 27 in. in breadth. It is claimed that ridging, in addition to facilitating horse-hoeing, gathers the fine soil under the plants so that they develop their roots easily and begin active growth quickly; it also means that artificial manures are gathered near the roots where they are most required, hand-hoeing and singling can be done cheaply, and the plants suffer less injury in the processes than when the crop is grown on the flat.

In many of the dry districts of England turnips are sown on the flat, in drills 18 to 20 in. apart, because it is said that the extra surface exposed when ridges are made allows the soil to become so dry that the crop cannot thrive. Many authorities recommend that wherever the annual rainfall is less than 24 in. this method should be followed. On clean land sowing on the flat is perfectly satisfactory, but if the land is weedy and the turnips receive any check in their early growth, the weeds spring up to such an extent that it is almost impossible to pick out the drills, horse-hoeing is delayed, and the turnips may be choked out altogether.

As a rule, swedes are sown between the second week and the end of May, and turnips about a fortnight later; but in hot, dry districts, such as the south of England, where mildew is apt seriously to affect the early sown crops, seeding does not commence until the last week of June. On the other hand, swede sowing may occasionally commence in April. It is advisable to allow short intervals between the sowings, and to sow only a few acres at a time so that the whole area will not reach the singling stage simultaneously.

The average seed rate is 3 lb. per acre for turnips and 4 lb. per acre for swedes. Where a good tilth has been prepared, thin sowing allows the plants to grow quickly and makes them easy to thin, but where turnip-fly is apt to be

injurious, a thick seeding should be given to ensure that all the plants will not be destroyed. A relatively heavy seeding is also used on heavy land or where sowing is abnormally early. In the former case the unsuitable nature of the tilth will lead to diminished germination, and in the latter a high mortality among the seedlings must be expected.

The machines used for ridge sowing take two drills at a time, and are fitted with rollers to pack the soil about the seed and to encourage the rise of capillary moisture; but many light-land farmers like to follow up the drill with a light roller so as further to increase this consolidation. The machines used for drilling on the flat sow four drills at a time, and sometimes water drills are used which deposit a certain amount of water with the seed.

Manuring.—Although turnips can be successfully grown with artificial manures alone, they are so dependent on the texture and the moisture content of the soil that farmyard manure should be applied whenever it is available. It is useless to attempt to grow turnips without manure of some sort, as no crop is more quickly affected by soil poverty. If necessary, of course, artificial manures may be used alone, and indeed in some rotations most of the dung is used for the potato crop and it is impossible to make an allotment to all the roots grown. When a limited quantity of muck, say 8 to 10 tons per acre, is available, the best results will be got by supplementing this with suitable artificials. It is found that nitrogenous fertilisers do not increase the crop to any great extent if farmyard manure has been applied; this is probably because the growing period is at a time of the year when high temperature and constant cultivations activate the soil organisms and cause the release of abundant nitrates; moreover, such increase as they do produce is mostly water and tops. The phosphatic fertilisers give very different results as phosphates frequently prove the limiting factor in the yield. About 4 cwt. of superphosphate, or an equivalent of bone flour or basic slag in light and heavy land respectively, is normally required in addition to a moderate dressing of dung, and produces during the seedling stage a remarkably

rapid growth which is of enormous advantage to a crop of the nature of turnips. It is not, as a rule, necessary to apply potash manures along with dung except on very light or peaty soil.

A suitable manuring for average conditions would be 10 tons of dung, 4 cwt. of superphosphate and ½ cwt. of sulphate of ammonia, which last gives better results than nitrate of soda because of the shallow rooting habit of the plants. When no dung is available, 5 cwt. of superphosphate, 1¼ cwt. of sulphate of ammonia, and ¾ cwt. of muriate of potash should be applied. The limit of profitable manuring, however, may in certain cases be higher.

Concerning the time and manner of applying the various manures there is a considerable difference of opinion. On the light class of soils it is perhaps better to spread the dung in the autumn and plough it in immediately, as this greatly increases the capacity of the soil for water, and may result in a satisfactory crop when other land that has received no dung contains too little moisture to swell the seed and promote germination. If it is found necessary to manure in the drills in the spring, the dung should be short and rotted so that it will not interfere with the capillary rise of soil water. If the only available manure is long and unrotted, it should be turned over so that it will ferment and break down, even if a loss of nitrogen is occasioned thereby.

Subsequent Cultivations.—Usually the first implement that is used when the plants have appeared through the ground is the scuffler, which pares down the ridges to some extent and greatly facilitates the task of singling; but if the land is dirty this may be preceded by horse-hoeing. In an average season the plants are in rough leaf about three weeks after sowing and then the sooner they are singled the better. The usual distance to which turnips are singled is 9 in., but it may be anything from 6 to 12 in., depending on the quality of the soil and the habit of growth of the variety. Singling is usually carried out with a hand-hoe, but in some districts where small acreages are grown it is performed entirely by hand, or the hoe may be used only to give a

preliminary bunching. Suitable machines are now on the market which bunch the plants to any desired interval, and make singling a less lengthy and less costly process. Whichever method is employed it is of the utmost importance that the work should be carefully and thoroughly done, as the yield of the crop can be greatly reduced by carelessness. Unless trustworthy and skilled labourers can be secured, it is not advisable to have singling done by piece-work. The workers should be instructed to strike out all weeds that have established themselves between the rows when they are going over the ground. In order to save the cost some poor-land farmers, who intend to eat the roots off with sheep, do not single the plants, but reduce their numbers by dragging a cultivator across the drills.

When singling is over the plants are kept free from weeds, and the soil well aerated by hand-hoeing and by a series of drill cultivations, until the foliage is so large that it is liable to be damaged. Sometimes the crop is lightly ridged up before it is left, in order to assist surface drainage; but on light soil it is questionable if the operation has any advantage.

Lifting Turnips.—In a mild season turnips go on growing right up to New Year, but when the leaves fall away the crop may be considered as mature and may be removed when it is required. White turnips, which are usually grown in small quantities only, are generally fed with their tops to animals on the grass in September, or they may be fed off with sheep. Yellow turnips are ready for use in October, and swedes about the end of November. From November onwards it is the custom in most districts to remove the turnips from the land and store them for winter feeding; but they may be treated in any of the following ways:—

1. In mild districts, and where the crop is grown near salt water, the turnips may stand out all winter and be removed when required. They may also be allowed to stand out in poor districts where the roots are small and hard, and are hence not liable to injury by frost.

2. The turnips may be left growing in the fields and fed off as they stand on the ground.

3. They may be stored in small clamps, containing about four loads each, which are distributed over the turnip field or on a stubble, and roughly covered to protect them until they are sliced for sheep feeding in the winter months.

4. Turnips may be protected in the field by ploughing them in. This is done by ploughing out a furrow, lifting two rows and placing the roots in the bottom, and then ploughing the soil back to give them a good covering. Turnips stored in this way probably keep better than when they are preserved in any other manner; but owing to the large quantity of soil which adheres to them during wet weather, a lot of labour is required to clean the roots after they are lifted.

5. The most usual method of storing, however, is to cart the roots to a suitable spot in the vacinity of the feeding sheds and place them in long, broad clamps, well covered with straw to protect them from frost.

In all cases where the bulk of the turnips is allowed to remain in the fields during winter, it is necessary to keep a supply in the farm buildings which will be sufficient for the wants of the animals during any ordinary spell of hard weather.

Yield.—The average yield of turnips for the whole country is about 14 tons per acre; but in the typical turnip districts of the north 20 to 25 tons can easily be grown, and, on the other hand, 10 to 12 tons is an average crop on some thin soils.

Growing Turnip Seed.

Instead of purchasing turnip seed it is an easy matter to grow all that is required for use on the farm. To do this, good, solid, shapely mother-roots, which are entirely free from disease, should be selected and transplanted to a sheltered spot, giving each plant about a square yard of ground, so that they will remain in good condition throughout the winter. Shooting takes place early in the following season, and it is helpful to remove some of the small top branches so that every chance is given for the production of

good, large seed. The shoots should be cut as soon as they are ripe and stored in an airy shed until they are dry and brittle. When threshing has taken place the seed should be passed over a riddle and the small specimens discarded, as it has been shown that the largest seeds produce the biggest and most robust plants. Before storing, the seed should be dipped in paraffin to protect it from insect attacks.

The ordinary routine adopted by seedsmen is to broadcast, in late summer or early autumn, "stock-seed" obtained from selected bulbs and to allow the resulting crop to "run to seed" altogether. Commercial crops thus represent the second generation from the selected plant. Commercial seed is grown chiefly in the eastern and south-eastern counties of England.

Fungoid Diseases.

Finger-and-Toe.—This disease is due to the attack of a slime fungus which finds its way into the growing root tissue from the soil. At first the affected plant is unthrifty in appearance and its leaves are somewhat wilted. An examination of the root reveals the chief characteristic of the disease—the presence of malformations or "club roots" due to the stimulating action of the fungus which multiplies rapidly within the cells. The root, of course, is stunted and small and afterwards decays.

The longevity of the fungus makes it difficult to deal with; but it is found to be most persistent on land that is definitely sour. An ordinary degree of acidity can be remedied by applying 30 cwt. to 2 tons of slaked lime per acre, the influence of such dressings on the activity of the organism being most marked when they are applied in the autumn six or eighteen months before the turnips are to be sown. When it is practicable to lengthen the rotation or to put the worst infected fields down to grass for a period, the fungus is either eradicated or its activity greatly reduced. A point that should never be overlooked when turnips have to be grown on badly-infected soil is the selection of varieties that are resistant to the disease, as it is possible

to obtain strains that are only affected to a slight degree. It is, of course, recommended that cruciferous weeds should be suppressed, and care should be taken to destroy diseased roots or to reserve the dung made during their consumption for other crops; but these points are difficult to carry out in practice.

Turnip Mildew.—A number of species of leaf mildew attack the leaves of turnips and other cruciferous plants, the greatest damage being sustained in the southern counties where the growth of the crop is apt to be retarded by hot and dry weather.

In southern districts turnips are sown a month later than in other places, because they are then found to suffer less than when early sowing has brought about a considerable development of foliage by the time the hottest and driest season is reached. If seedling turnips are found to be affected, they should be singled at once, so that each plant may have room to develop and the competition for the available soil moisture may be reduced.

Insect Pests.

The Turnip Fly.—On walking over a crop attacked by "Fly," attention is drawn to the presence of the insects by the rapid jumps they make when disturbed. The beetle is only about one-tenth of an inch long, and can at once be recognised by the broad yellow band running down each wing cover. These flea beetles breed rapidly in a favourable season, as many as six generations being possible in one year. The damage caused to turnips is enormous, as the beetles attack the delicate seed leaves as soon as they are through the ground, and in a season when growth is slow, the plants may be eaten off altogether. When the plants have reached the rough-leaf stage they may be considered safe, but it is sometimes necessary to sow the crop three or four times before it can establish itself.

It is almost impossible to get rid of a bad attack of this pest, but it may be possible to make the young plants obnoxious to the insects by dusting them over with a powdery

substance, such as superphosphate, early in the day when the leaves are damp with dew; or a flock of sheep can be driven over the dry land to stir up the dust. It is also advisable to soak the seed in paraffin before sowing as this helps to keep the beetles away.

Other insects that attack turnips are Surface Caterpillars; the Silver Y-Moth; the Turnip Sawfly; the Turnip Mud Beetle; the Turnip Gall Weevil; the Diamond-back Moth, etc.

THE MANGEL.

Mangels are supposed to have been evolved by a long process of careful selection from the wild sea-beet, which is still found in many temperate districts. Although cultivation of the crop was not commenced in this country until many years after the usefulness of the turnip had been established, the acreage has steadily increased, and at the present day mangels are being introduced into many of the northern turnip-growing districts because of their value for late feeding.

The mangel "root" consists of part of the stem immediately below the cotyledons and part of the true root tissue enlarged and modified as a food reserve. Transverse sections show the concentric ring formation so well known in the garden beet. Like the turnip it is biennial, but by special methods it can be made to produce its seed in a single year.

The mangel crop is capable of yielding more dry matter per acre than any other crop of a similar nature, and the greater part of its food material is in the form of sugar. The yield is highly elastic, and can be influenced greatly by manuring. Indeed, where conditions are suitable and manuring is understood, crops of over 50 tons per acre can be profitably grown.

The rôle of the mangel in the economy of the farm is similar to that of the turnip, but where climate and soil are favourable it is a better yielder. It is less liable to parasitic infestations, is a more certain cropper, and keeps

better than any cruciferous root. The mangel is superior to the turnip as a food for dairy cows, as it does not taint the milk nor spoil the flavour of the butter. As a food for sheep, however, mangels are not so satisfactory as turnips; although they can be safely fed to ewes and lambs, they tend to produce urinary disorders in male sheep and are unsuitable for hoggs. In all cases, however, it is essential that mangels should be properly ripened before they are offered to stock, as immature roots cause the animals to scour badly. Because of their liability to injury by frost mangels have to be lifted before they are properly ripe. The lifting of the crop is therefore followed by a period of maturation, during which the simpler nitrogenous bodies are converted into stable proteins and the sugars into cane-sugar. In order to allow these changes to become complete, farmers, as a general rule, do not feed mangels to stock before Christmas. In most cases the leaves are left on the field and returned to the soil as manure, but in years of scarcity they can be used in limited quantities for feeding purposes.

Varieties.—With mangels, as with turnips, the number of named varieties is so large that it is impossible to describe individual sorts in this work. Mangels, however, can be broadly divided into four groups according to their shape, viz.: Longs, Intermediates, Tankards, and Globes.

The *Long* varieties may be red or yellow in colour, and are three or four times as long as they are broad. They are deeply buried, and yet stand more than a foot out of the ground, thereby being rather susceptible to early frosts. They are suited only to good, deep soils that are neither too strong nor too stony, and under suitable conditions give the heaviest crops and a return commensurate with extraordinarily liberal manuring. They are, however, rather coarse and fibrous, and have a poorer feeding value than the other sorts, and they are somewhat difficult to lift owing to the depth to which their roots penetrate the soil.

The next type is the *Intermediate*, which is an elongated oval in shape, yellow, orange, or red in colour, and in quality is intermediate between the longs and the tankards.

The *Tankard* is a parallel-sided type which rounds off abruptly at the neck and root; it is shorter than the intermediate but quite as broad, and is red or golden in colour. The yield is smaller than in the case of the other varieties, but the feeding quality is unsurpassed.

The *Globe* is roughly spherical in form, commonly yellow in colour, and grows with all but its true root out of the soil. Because of its habit of growth a globe mangel does well on a shallow soil, and is very easily secured at "lifting-time." The feeding quality is almost as good as that of the tankard, but owing to its softer nature the root is not quite such a good keeper. Its bulk, however, is greater.

The best varieties are those that produce the greatest yield of dry matter per acre, are solid and of good keeping quality, and do not tend to bolt in their first season's growth.

Cultivation of Mangels.

Soil and Climate.—The mangel is the typical root crop of all the heavy classes of land, but it grows best in a deep, rich loam, and fails utterly on a poor, thin upland. Since mangels do best in sunny, dry climates, they occupy the greatest percentage of the root crop area in the southern and eastern counties. Actually they are more dependent on sunlight than on high temperature, and once established they are highly resistant to drought; they do well where heat and drought preclude the growth of cruciferous roots. It is in the midland counties, however, that mangels grow to perfection. In Scotland the climate is too dull and cold for the best results, and there is an increased tendency for the plants to bolt; but many dairy-farmers are now cultivating a small acreage for early spring use.

Place in Rotation.—Mangels, of course, occupy the same place in the rotation as the turnip crop, because they facilitate the cleaning of the land in the same way. They cannot, however, be taken after a spring-consumed forage crop as they have to be sown early; but they have a distinct advantage in that they can be grown continuously on the same land without their yield being diminished by disease.

Preparation and Sowing.—The preparation depends on the variety to be grown and the nature of the soil, but the usual procedure is to spread the dung in autumn and to give the land a deep ploughing which will leave the soil in a good condition to benefit by the winter weathering, and finally to work the soil to the required fineness of tilth before seed-time; but on dirty land cross ploughing in spring may be necessary, though care must be taken to avoid bringing the manure to the surface.

A useful way of getting well forward with the work for spring is to plough in autumn, to work the land into a rough mould and to draw it up into ridges. The dung is then spread in the drills, the ridges are split back, and the field is left throughout winter. All that is necessary in spring is to harrow down the frost-broken clods, spread the artificial manures, run up the ridges, and then sow.

Although ridging is more common, mangels may be sown on the flat if the land is sufficiently clean (*see* Sowing of Turnips). The distance between the drills varies from 22 to 30 in., and the plants are singled to intervals of from 8 to 15 in., more room being given on good land that is capable of growing large plants. When plants are being specially developed for exhibition purposes it is customary to give each one at least a square yard of ground.

Commercial seed consists of what is really the fruit of the mangel, each fruit containing one or more seeds, and a germination test will, as a rule, give fully 120 per cent. of plants. This "seed" is extremely hard, and many farmers soak it in water for about twenty-four hours before sowing so that germination may take place more rapidly. If this is done, however, it becomes necessary to spread the wet seeds out so that the superficial water evaporates, otherwise they will stick together when passing through the drill. The amount of seed sown varies from 6 to 10 lb. per acre, the larger amounts being employed when the conditions of soil and weather are least favourable. Any seed that is left over can be kept for sowing in the following season as it does not lose its vitality for several years.

In the Midlands of England the ideal time for mangel-sowing is the second week of April, but in the southern counties seeding must take place about a month later because the plants are apt to bolt when their growth commences too soon. The Scottish crop is sown about the middle of May.

It is said that by growing "Longs" and "Globes" in alternate rows an economy in space is effected, and a better yield per acre results.

Manuring. — The most important and widely-used manure for mangels is dung, and it is seldom attempted to grow the crop without its aid. It has been found, however, that dung alone does not supply nitrogen fast enough for the best results, and a moderate dressing, supplemented by artificial fertilisers, will produce a greater yield than an excessive application of the natural manure. At Rothamsted it has been shown that nitrate of soda is a more suitable form of nitrogenous artificial than sulphate of ammonia, and this finding probably holds good under most farm conditions. With regard to the mineral manures, mangels are less dependent upon phosphates than are turnips, but require a more liberal supply of potash. Mangels respond also to an application of common salt; but it is questionable if the action is a direct one, as many believe that salt liberates potash from the decomposition products of the potash felspars in the soil so that the benefit to the crop is indirect. Bearing this in mind, it is worthy of note that most of the crude forms of potash salts at present on the market contain a considerable proportion of common salt, and therefore have a particular value when applied to mangels.

As regards the application of the manures, some farmers apply the common and potash salts a considerable time before sowing is to take place, so as to prevent any injurious effect upon the young seedlings; but this should only be necessary where exceptionally heavy dressings are employed. Ordinarily the salt, potash, phosphates, and a proportion of the nitrogenous manure should be applied immediately before ridging, and the remainder of the

nitrogen should be applied as top dressings when active growth is established.

The quantities of manure which can be profitably applied depend on the condition of the soil. On land of good depth and good texture the crop responds to heavy dressings more readily than on poorer or shallow soils. The amount of potash supplied should be proportional to the nitrogen, even on heavy land that is rich in potash.

The following is suggested as a suitable dressing under good conditions :—

15 tons of dung—ploughed in in autumn or applied in the ridges.
2 cwt. of 20 per cent. potash salts
3 cwt. of common salt
4 cwt. of 30 per cent. superphosphate
¾ cwt. of sulphate of ammonia
} distributed before seeding.
¾ cwt. of nitrate of soda—broadcast at singling-time.
¾ cwt. of nitrate of soda—broadcast six weeks after singling.

After-Cultivation—The growth of mangels being at the outset slower than that of turnips, horse-hoeing is, on dirty land, frequently necessary before thinning; this is difficult to perform unless the plants are growing on ridges. However, some farmers mix a few seeds of rape or other quick growing plant with those of the mangel in order to show the rows early. The rape plants are knocked out during singling. As a rule the crop is ready for thinning about four to six weeks after sowing; but in some districts a preliminary bunching is given, and the plants are afterwards carefully singled to about a foot apart. When deciding the distance to which the singling is to take place, it should be remembered that roots of medium size have a higher feeding value than those allowed to grow very large, and the greatest yield of nutrients is obtained from a crop somewhat below the maximum weight per acre. The yield is very seriously reduced if the crop is in the slightest degree "blanky," and the greatest care should be taken to fill up the spaces with cabbages or kohl rabi, which, when the soil is somewhat dry, bear transplanting better than mangels.

The tillage operations for the suppression of weeds are

the same as for the turnip crop, and must be carried out until the leaves meet in the drills, care being taken to prevent any of the weeds from seeding, otherwise much of the cleaning effect of the crop is lost.

Towards the end of the growing period a proportion of the mangels usually "bolt," or produce their reproductive shoots. In some seasons the proportion is very small, but in others, especially in the northern districts, shooting is very troublesome. If bolting is allowed to go on, the shoots draw upon the reserves of food material in the roots and the yield is reduced. It is therefore advisable to go over the crop early in September and cut down any shoots that are beginning to form. It has recently been shown to be possible to produce non-bolting strains.

Securing the Crop.—As mangels are able to withstand only very slight frosts, it is usual to secure and clamp the roots towards the end of October. Lifting is generally performed by two workers together, taking two drills apiece, and dropping the mangels in the drill between them when they have cut off the tops. In this way four drills separate every row of topped mangels, and this is ample room for taking through a cart when carrying takes place. If, however, the roots are not to be carted at once they should be collected into heaps containing about one-fifth of a load each and covered over with leaves, since, whereas growing mangels are protected from frost by their tops, bare roots are destroyed at very little below freezing-point. This practice is also believed to improve the keeping quality, as mangels "sweat" a little immediately after pulling; if taken directly to the clamp, and especially if they have been pulled before their growth has ceased, they are apt to suffer serious loss through fermentation, heating, and decay.

It is very important to avoid injuring the roots, and on no account should they be "tailed" or loaded with a fork. Injuries caused in these ways often give rise to bacterial decay and the destruction of a large proportion of the crop.

As a rule mangels are stored in clamps in the vicinity

of the feeding courts or sheds. In most cases the clamps are made as large as the roots can be conveniently heaped, because, once the first "sweat" is over, they can be kept in bulk without fear of further fermentation. Buildings that are well thatched can be filled almost to the roof, or clamps may be built against a wall, or between two parallel walls, to a great depth. Nevertheless, a good covering of straw is essential as the outer roots are very easily frosted.

Yield.—The average proportion by weight of tops to roots is 1 to 5. The average yield per acre for the whole country is about 21 tons, but 25 to 30 tons can be grown with ease in typical mangel-growing districts, and over 50 tons in favourable seasons where manuring and cultivation are carefully attended to.

Growing Mangels for Seed.—Most mangel seed is grown in the southern districts, and the system is interesting in that one year only is required for seed production.

The seed should be sown in a well-prepared bed about the beginning of August, and in order to get a quick, strong development of the seedlings a fair dressing of superphosphate should be first raked in. Early in October the plants should be sufficiently strong and forward for transplanting, and the land on which the seed is to be grown should be ready by this time. The preparation of the land consists of ploughing in a good dressing of dung, working the soil into a fair tilth, broadcasting a dressing of superphosphate, potash salts, and a little sulphate of ammonia, and then rolling. As the plants require a lot of room for the last stage of their growth the land should be marked off so that each plant receives about a square yard. The plants should be dibbled in when the ground is somewhat damp, and the soil should be well consolidated about the roots.

During the winter months the plants may look rather backward, but growth will commence with the lengthening days, and only very severe frost will cause injury. In the spring any blanks caused by plants dying-off should be filled from the seed-bed, where a number of seedlings should have been left for this purpose.

Their early start will rapidly carry the plants to maturity, but they should be assisted by giving a moderate dressing of nitrate of soda, and weeds should be kept well in check. When the first reproductive shoots have developed the field should be gone over and the tops of the shoots cut off, so that the lower branches will spread and occupy the ground.

When the first seeds begin to harden, the crop should be cut with a hook, tied in bundles, and stooked to dry. When drying is completed the crop can be stacked, or threshed right away if necessary. The yield varies from 10 to 20 cwt. of seed per acre.

If a farmer produced his own seed in this way he would have to sow a little thicker than usual, as an ordinary thresher cannot produce such a perfectly dressed sample as is marketed by seed-merchants.

In colder districts where plants could not stand the winter, seed could be produced by preserving a few roots and setting them out in the following spring, as is described for turnips.

Diseases of Mangels.—Mangels are singularly immune from serious disease infestations, and although they are attacked by quite a number of insects and fungi, the severity of these attacks is not sufficient to warrant their description in this work.

CARROTS.

Our cultivated carrots have been obtained from the wild carrot, which is a common annual or biennial weed, by a process of selection which has fixed a biennial habit and a fleshy root. There are numerous varieties varying from the small, sweet garden sorts to the large, white-fleshed field carrots which are grown exclusively for stock.

When stock carrots are grown on the farm they are usually kept for horses and pigs. For horses they are excellent succulents, are greatly relished, and are believed to improve the sheen and appearance of the coat. They form useful food for pigs, especially when the animals have no access to grassland and green foods, keeping them in good health and stimulating their appetites and digestions.

Carrots grow well under all our climatic conditions, but they are never grown to any great extent except on deep, open, sandy or loamy soils. No attempt should be made to grow field varieties on shallow or stony land as the crop is certain to be inferior and unprofitable.

It is important that deep cultivation should be given in preparing land for carrots, and if there is even the slightest pan it must be broken up by subsoiling. When the deep working has been completed a fine surface tilth should be prepared as for the turnip crop, and the ground must be thoroughly cleaned. The importance of clean land for carrots cannot be overestimated, as the seedlings are so slow-growing and delicate that they cannot compete with weeds, and, moreover, on weedy land singling is practically impossible.

The seed may be obtained either in its natural state or with its bristles machined off. In the former case it is difficult to sow as the appendages cause the seeds to cling together, and before being put through the seed-drill it should be mixed with a large bulk of sand or dry soil. About 4 lb. of seed is sufficient to sow an acre, and it should be drilled on the flat in rows about a foot apart. Singling should take place to intervals of 4 to 5 in. The seed must not be placed too deep (an inch is sufficient) or the plants will fail to come to the surface.

Carrots respond to liberal dressings of artificial manures used in conjunction with dung; but the best quality is obtained when the dung has been applied to the previous crop and is well rotted and mixed through the soil. Unrotted dung tends to make the carrots fork and reduces their value. A suitable manuring would be 10 tons of dung ploughed in early in autumn, 3 cwt. of superphosphate, and 1 cwt. of sulphate of potash put in with the seed, and 1½ cwt. of nitrate of soda put on as two top-dressings at intervals after the plants have established themselves.

The subsequent cultivations consist of keeping the land thoroughly clean by hoeings. When the plants are strong enough singling is done either by means of a small hoe or by

hand, small intervals being employed when the crop is to be lifted in an immature state for the early market.

Although carrots can stand a certain amount of frost it is usual to lift and store them in October or November. The lifting is usually done by two workers, one loosening the soil with a fork while the other draws out the root. The roots are stored in small clamps built after the fashion of potato pits, and provided with a ventilating shaft of straw to prevent overheating.

The average yield of mature carrots per acre is about 12 tons.

The chief pest of the carrot is the larva of the carrot fly. The fly lays its eggs in the soil round the plant roots, and the maggots eat their way into the root tissue causing the plants to wilt and "go off," and not only destroy a large proportion of the plants, but reduce the marketableness of the remainder by unsightly tracks and burrowings. The only way to prevent attack is to sprinkle substances round the seedlings which will keep the flies at a distance. Paraffin is sometimes used in the form of an emulsion, or it may be mixed with an absorbent such as sawdust or ashes, and broadcast over the bed; but as the effects of paraffin are not lasting, the dressings have to be repeated at intervals. Carbolic sheep dips are also used with success.

KOHLRABI.

In the kohlrabi that part of the primary stem above the cotyledons thickens and develops into a turnip-like food store. This "bulb" grows entirely above ground, and as it thickens the lower leaves fall away leaving characteristic broad scars. There are two main classes of varieties, the one being entirely green and the other purplish.

Kohlrabi takes the place of a root crop in the economy of the farm, and can be safely fed to all classes of stock. As a food for cattle it is excellent, and it has a particular value for dairy cows in that it does not taint the milk as do turnips. When fed to sheep it is usually eaten off, and it

is more economical than swedes, as only the little thin roots are left in the ground. Large quantities are fed to pigs, and as its nutrient value is much higher than that of the mangel, it has been found that sows, having the run of a little grassland, can be kept on kohlrabi without the addition of concentrates between the weaning of one litter and the approach of farrowing. It is also largely used in many of the modern systems of open-air pig-keeping. Kohlrabi is used for culinary purposes on the Continent, and is generally prepared like a dish of turnips.

The crop is largely grown on the stiffer class of land, and its requirements are more akin to those of the mangel than to those of the turnip. For this reason kohlrabi is often grown in southern districts where turnips form an uncertain crop.

In growing kohlrabi the land is prepared as for turnips, and sowing takes place in April. The seed is sown on the flat at the rate of 4 lb. to the acre, and the drills are 18 to 24 in. apart. When the plants are sufficiently forward they are singled to intervals of 10 to 12 in. Sometimes the plants are started in a bed and dibbled in by hand in May or June; and because they can be transplanted very successfully, many farmers sow out a small bed in March and use the plants to fill the gaps in their mangel fields.

In the manuring of the crop it is usual to apply a moderate dressing of dung supplemented by artificials, but the plants do not respond to nitrogenous dressings as well as mangels or cabbages. A suitable manuring would be 12 tons farmyard manure, 4 cwt. superphosphate, 3 cwt. kainit, and 1½ cwt. nitrate of soda in two dressings.

It is usual to feed the crop in the autumn, but if necessary the bulbs can be stored in clamps like turnips. If a hardy variety is selected, however, the plants may be allowed to stand out until well into the winter and lifted as they are required.

CHAPTER IV

SUGAR BEET

SUGAR BEET is a biennial plant closely related to the mangel. It differs from the mangel in that its parsnip-shaped "root" develops in the ground and only the crown bearing the leaves appears above the soil. Sugar beets are white coloured; their average weight is about 1½ lb.; they do not "bleed" like mangolds and garden beet when cut; they have a high dry matter content, their sugar content alone amounting to from 15 to 20 per cent. of their weight.

The sugar beet of to-day has been developed from the wild beet by breeding and selection, which has been carried out with the primary object of obtaining a maximum yield of sugar per acre. The early work of improvement took place in France and Germany, but beet cultivation has now extended to every country in Europe, to America, and to many other temperate countries throughout the world. Although the main object of growing beet is the production of sugar, the tops and leaves are removed before the crop is marketed and they form a satisfactory food for stock, or, if they are not required for this purpose, they can be ploughed in as manure. Plants that bolt during the growing season are frequently dug out and fed to cattle or sheep on the grass.

Beet pulp, which is the residue of the roots after the sugar has been extracted, is a very valuable substitute for the ordinary root crops. In the wet state it is of rather poorer feeding value than white turnips, but it is nevertheless the only succulent food given to many continental herds during winter. The wet pulp is costly of transportation, and it is therefore used mostly by farmers in the vicinity of the factories; it can be stored in pit silos, either with or

without the addition of the tops and leaves, for long periods. Most factories also produce dry pulp in which the moisture content is reduced from about 93 to 11 per cent. The dried pulp is of course much less bulky and it can be sent long distances at relatively small cost; it can be stored in bags for an indefinite period. In feeding value 1 lb. of dry pulp is probably equal to 7 lb. of swedes or mangolds, or to 10 lb. of soft turnips, and it follows that about 7 lb. of dry pulp may be employed to take the place of a 60 lb. root ration. The dry material is generally swelled by soaking it in water before feeding, but soaking is unnecessary provided the animals have access to water.

The Extraction of Sugar from Beet.—For the extraction of beet sugar, factories are erected in districts which are likely to be suitable for the cultivation of beet in quantity. The crop is grown for the factories at a contract price per ton of washed beet containing a standard percentage of sugar, and a bonus is given where the sugar content is above this standard. The work of extraction commences about the beginning of October and the last beets are usually disposed of by the middle of January; for the remainder of the year the factories are idle and employ only a maintenance staff.

The beet is consigned to the factory as it is required, and on its arrival a representative sample is taken in order to estimate the "tare" and the sugar content. The "tare" is the difference in weight between the beets as delivered in a more or less dirty condition and the same beets after washing and, if necessary, dressing; it generally amounts to from 10 to 20 per cent. of the gross weight. The sugar content is estimated in the factory laboratory. As the farmer gets nothing for the tare on his consignment but has to pay carriage thereon, it is obviously in his interest to deliver the roots in as clean a condition as possible, and properly topped.

In the manufacturing process the beets are first washed, and after weighing they pass to the slicing machines which reduce them to fragments suitable for extraction. The

sliced beet then passes to one of a battery of cylindrical diffusers which are so arranged that each fresh batch of sliced material is extracted with hot juice, circulated from the other cylinders of gradually decreasing concentration until finally hot water is pumped through to remove the remaining sugar. The residual pulp is removed and sold, either wet or after desiccation, for stock feeding. The purification of the juice from the diffusers is brought about by the addition of lime and the subsequent precipitation of the lime with carbon dioxide. The carbonate of lime is removed by filtration and, being of no further use, can be bought very cheaply from the factories. For agricultural purposes, however, it has the disadvantage of being very wet. The juice is next evaporated to a syrup and, after further purification, it is concentrated in vacuum pans by boiling at a sufficiently low temperature to prevent caramelisation. When the crystals are sufficiently formed, the material is centrifuged to remove the non-crystallisable matter, which is the by-product known as molasses or treacle.

An alternative arrangement for beet sugar production, which is still in the experimental stage, is one whereby the beet is pulped and dried in small local factories working only during the lifting season. The dried material then goes to a central sugar-extracting factory, which is provided with sufficient storage accommodation to keep its plant going the whole year round.

Quality and Varieties.—Beet roots should average 1 to 2 lb. in weight, richer soils producing the larger size; the shape should be that of a nicely formed tap root without any tendency to forking or fangy growth. There should be no coarseness about the crowns, very little of which should appear above the ground. A well-developed leaf system is essential for a good crop, but an over-development due to excessive nitrogenous manuring is often correlated with lateness, poor root development, and reduced sugar content.

A high sugar content is desirable and this is usually more easily obtained by growing a large number of small roots on a given area than by having larger and wider spaced

plants. The sugar content, however, must be considered in conjunction with the yield. On the Continent three general types of beet are recognised. The first produces a large yield but possesses a relatively low sugar content. At the other extreme is a type producing a small yield but having a high sugar content. The third or normal type is intermediate between these two. The farmer selects a variety of the type that is most likely to suit his conditions and yield him the greatest profit. If he has land like our Fens, which naturally produces large roots of poor quality, he selects a variety of the small rooted type with the high sugar content. If his farm produces a very rich root but a poor tonnage per acre, he selects a big rooted variety. While a high sugar content is usually most desirable from the factory owner's point of view, a relatively low sugar content but a big yield may easily be more profitable for the grower.

Bolters in crops of sugar beet are very common, and they are extremely undesirable as their roots become woody and of little value for sugar extraction. While the proportion of bolters is undoubtedly influenced by the date of sowing, and also perhaps by the manuring, bolting is an hereditary characteristic and is more common in certain varieties than in others.

When a farmer contracts to grow beet he is obliged to sow the seed the factory supplies to him. Although he may be offered a limited choice of varieties, all the varieties are chosen by the factory managers as being suitable for the district. The seed of the varieties that are being grown at the present time is purchased from continental seed growers and sold to the contracting farmers at cost price. Among the sorts which have done quite well in this country are Klein Wanzleben, Bergmann, and Schreiber.

Beet Cultivation.

Soil and Climate.—The best soil for beet is a deep free-working loam, but the crop has been grown quite satisfactorily on well-drained soils of practically all types. Light soils

have the advantage of being warm in spring and thus enabling the young plants to establish themselves more quickly; they also allow of the crop being lifted in a somewhat cleaner condition, and they do not suffer much damage during a wet harvest season. Stony soils are unsatisfactory because they cause the roots to fork, and soils that possess a pan are quite unsuitable for growing beet until the pan has been broken up by deep ploughing or subsoiling. Beet cannot be grown profitably on land that requires liming, and it is well worth having the lime requirement of the soil estimated before trying to grow the crop. With regard to quality, it is found that the highest sugar content is obtained when the beet is grown on light land and the lowest on peaty soil.

Sugar beet is so widely grown that it cannot be said that its cultivation has many climatic limitations, and it has been shown that this country, on the whole, has a climate very suitable for growing the crop on a commercial scale. At one time sunlight was thought to be necessary for sugar production, but it is now realised that it is daylight that matters, and countries in northern latitudes with their long summer days actually produce roots containing the highest proportion of sugar. Owing to the infrequency of hard autumn frosts in Britain, the roots—which withstand 8 degrees of frost when lifted, and more in the ground—do not require any special storage, and the lifting and manufacturing period can be of relatively long duration. One disadvantage of our climate for beet cultivation is the frequent occurrence of cold spells in spring which may affect beet at a critical stage of development and cause bolting.

Place in Rotation.—In this country beet is almost invariably grown in place of part of the root or potato crop, *i.e.*, between two straw crops where a maximum of benefit is obtained from the opportunity of cleaning the land. Beet may be grown for several years running on the same ground, but in some cases this practice has increased the incidence of parasitic infestations. The crop has also been taken after seeds. On land where the roots are liable to be fangy, it is

a good plan to cultivate the crop after roots that have been dunged, and to manure it with artificials only.

Preparation and Sowing.—In early districts it may be possible to clean the stubbles after harvest, and this should be done whenever it is practicable. In autumn or early winter the dung is driven out and spread in the usual way, and these operations are followed by ploughing. The ploughing should be as deep as the nature of the soil will permit, and in some cases it may be profitably accompanied by subsoiling; it should be done early so that the furrow slices get the benefit of long exposure to winter frosts. Most authorities are against cross ploughing in spring, maintaining that this practice turns down the frost mould and tends to dry the soil, thus hindering the preparation of a fine tilth and involving the risk of an unsatisfactory braird. In spring, harrows should be sufficient to prepare a fine surface mould, and cultivators or grubbers can be employed to break up the furrow slices to their full depth so as to allow of easy penetration of the beet roots. A full germination of the seed depends on an adequate moisture supply, and this is best secured by consolidating the surface soil with rollers, both before and after sowing.

The yield of the crop depends very largely on the number of beets that can be grown to the acre, and continental experience has shown that the greatest profit is obtained when about 40,000 plants are grown on this area. Allowing for a few blanks, such a number can be obtained when the rows are 14 to 16 in. wide and the beets are singled to 8 or 9 in. apart. When these spacings are employed not only will the tonnage be largest but the percentage and yield of sugar will be highest. Wider spacing will produce larger individual roots having a lower percentage of sugar, and as their size does not compensate for their smaller numbers the yield per acre will be less. In one series of continental experiments where the optimum distance between the rows was 14 to 16 in., the adoption of 18-in. drills reduced the yield of beet by 2 per cent., 20-in. drills caused a reduction of 3 per cent., and 22-in. drills gave 5 per cent.

less beet and reduced the sugar content by about $\frac{1}{4}$ per cent. On the other hand wide drilling allows of horse-hoeing being done much more easily and does not necessitate the purchase of special implements; it is better understood by British farmers and farm workers and involves less labour in singling, lifting, and topping the beets. It therefore becomes a question of economics—which the growers themselves must settle from a knowledge of their costs of production and the price of beet—whether it is worth while foregoing the advantages of cultivating the crop on wide drills in order to secure a few more tons of roots for sale and a slightly superior yield of sugar.

Sugar beet is usually drilled on the flat. This method has of course advantages with regard to the conservation of moisture in a dry climate, and it allows of the rows being placed closer together than is practicable with a system of ridges; it also insures that the crowns of the beets are not unduly exposed to light—which reduces the sugar content and necessitates the removal of the greened portion—and to the ravages of hares and rabbits. Notwithstanding the advantages of cultivation on the flat, many farmers, particularly in the north, prefer to grow their beet in ridges. Ridging greatly simplifies the subsequent cultivations and enables weeds to be kept in check from the outset. The crowns of beets growing on ridges need not necessarily become exposed if they are well earthed up.

The amount of seed that is recommended for sowing beet is from 15 to 20 lb. per acre. In theory this is considerably more than should be required; but as the subsequent yield of the crop depends so much on a full and uniform plant, and there are so many risks of mortality after sowing, it is found in practice that light seeding is a very false economy. It is only fair to point out, however, that where there is a combination of first class tilth and good weather conditions a heavy seeding may produce such a thick braird that singling becomes somewhat laborious. The seed should not be sown to a greater depth than one inch.

The sowing period extends from the middle of April to the middle of May, depending on the climate of the district,

and if growers sow their beet about the normal time for sowing their mangels the results should be quite satisfactory. There is a period in the life of the young plants when they are so susceptible to a set-back that cold weather — not necessarily frost—may cause them to bolt later in the season, and the actual date of sowing is therefore determined to a large extent by the risk of cold spells after the seed has germinated. The susceptible period lasts for about a week or a fortnight, and, when it has been passed, later spells of cold weather will not cause bolting. It is consequently quite possible for late sown beet to be so influenced by cold that it runs to seed, while an early sown crop, which has passed the susceptible stage, remains unaffected.

Beet may be sown with some makes of mangel drills, and, for sowing on the flat, it is even possible to make use of a corn drill if the unrequired coulters are put out of action. Where a large acreage of beet is being grown it is probably worth while to purchase a continental or American type of steerage beet drill that can be converted into a horse-hoe. Unless there is a special soil press on the drill, rolling should be carried out after sowing.

Manuring.—As has been previously pointed out the first essential in the preparation of the land for sugar beet is to insure that the soil contains an adequate supply of lime. There is as yet little reliable data on the manuring of the crop in this country, and growers are obliged to rely to a considerable extent on continental experience. There appears to be little doubt, however, that the most valuable manure is dung, which, if applied at the rate of 10 tons per acre, may produce a yield of about 4 tons per acre more than can be obtained by the use of artificials alone. Heavier dressings of farmyard manure do not give a corresponding increase of beet, and are liable to delay ripening and decrease the sugar content of the crop. The dung should be applied in autumn or early winter, and, even if the system of cultivation permits, dunging should not be done in the drill. Green manures may be used for beet but they are not so effective as farm manure.

With regard to phosphatic fertilisers, superphosphate is most commonly employed, about 2 cwt. per acre being applied in conjunction with dung, or twice this amount where the crop is being grown with artificials only.

Potash is essential for sugar beet, yet on soils that have plenty of body and contain considerable potash reserves it may be unnecessary to apply potash manures in addition to farmyard manure. On a few strong soils it does not even pay to use potash in the absence of farm manure. At the other extreme are sandy and peaty soils which are very poor in potash, and when beet is grown on land of this type it responds to dressings of up to 4 cwt. of kainit per acre in conjunction with dung, or twice this amount when no farm manure is employed. While kainit or low grade salts are recommended for sandy soils, muriate of potash is generally used on loams and on such heavier soils as may require potash.

The nitrogenous fertiliser which is generally preferred for beet is nitrate of soda; but where sulphate of ammonia is cheap it is probably quite satisfactory to use it for at least part of the dressing. The amount of nitrate of soda given on the Continent along with dung is from 2 to 4 cwt. per acre, and an extra 2 cwt. is employed when no farm manure is available. In this country it seems that the economic dressing is about $2\frac{1}{2}$ cwt. with dung, or $4\frac{1}{2}$ cwt. when only artificials are used.

The phosphatic and potassic fertilisers are applied at seed time together with part of the nitrogenous manure, the remaining nitrogen being reserved for top dressing the crop at a later stage. Where not more than 4 cwt. of nitrogenous manure is being applied, half may be given before sowing the crop and the remainder at the stage when the plants are being singled. If more than 4 cwt. is being used it may be advisable to give part as a second top dressing about a month after singling. Care should be taken to avoid the excessive use of nitrogenous fertilisers on land that is in a high state of fertility, otherwise the ripening of the crop will be delayed and the quality injured.

It is clear from the above that no standard manuring can be prescribed for sugar beet, because so much depends on the nature of the soil and its previous treatment. Nevertheless, where no precise local information is available, growers usually obtain quite satisfactory crops by employing the manuring which they have found to be satisfactory for mangolds.

Subsequent Cultivation.—In from ten to twenty days after sowing, according to the weather conditions, the sugar beet plants should be through the ground and the land may be given its first horse-hoeing. As soon as the beets reach the four-leaf stage, and when they are still very small, they should be singled. Early singling is of the utmost importance, and there are experimental data to show that the delay of the operation for a fortnight may diminish the final yield by over 30 per cent., while a delay of three weeks has resulted in the crop being reduced to less than half. In order to thin the plants to 8 or 9-in. intervals a 7-in. hoe should be employed, and the work must be done with very great care in order to insure that the best plants are left, that there are no blanks, and that the ground is thoroughly cleared of weeds. In many countries beet is thinned and the soil is consolidated about the roots of the selected plants by hand. Hand work is more thorough than can be accomplished with a hoe, and is probably worth while when the crop is being grown on suitable land, which will give a good return for intensive management, and where cheap labour is available.

Horse- and hand-hoeing are continued throughout the season until the plants are meeting in the drills. These operations are designed thoroughly to destroy all weeds, and it is possible that by moving the soil they improve fertility and help to produce a good crop.

The horse-hoes used for beet on the Continent and in America are designed to take two to five rows at a time, and they are consequently much more economical in use than the common single drill types; they are, moreover, generally fitted with discs which can be used for the early operations

in order to insure that the young plants are not covered with soil and smothered. A special hoe, or combined drill and hoe, should be got whenever a considerable acreage of beet is being grown.

In all probability a number of bolters will have to be dealt with during the growing season; indeed it is quite common for 5 to 10 per cent. of the crop to run to seed. In rare cases where the plants have had a check during the susceptible stage a greater number may bolt. Bolters are so poor in sugar and so woody that they are not worth sending to the factory and it is better to dig them out and use them for stock feeding.

Harvesting.—When beets are ripe the outer leaves tend to fall down and the whole of the foliage assumes a shrunken appearance. As the factories require beet from about the end of September, lifting commences about this time, although the beet is not fully ripe and has not developed its maximum sugar content. In November the beet is about its best, but the consignments despatched to the factories about the end of the year may have undergone some shrinkage. In order to give growers equal advantages in time of delivery it is usual for the factory managers to arrange to take part of each crop early in the season, part in the middle, and part towards the end of the extracting period.

Beet cannot be pulled by hand as can turnips and mangels, because it is far too deep rooted. Small areas can be dug with a special two-pronged beet fork, but whenever a commercial acreage is being grown the crop should be harvested with the aid of a special lifting plough. In one type of plough there are two lifting prongs with digging points placed so they enter the ground on either side of the row of beets, and as the implement moves forward the roots are caught on either side and wedged upwards clear of the soil. The other common type has one digging share which loosens the beets on one side and passes them upwards so that they are easily withdrawn. In some countries very elaborate machines are used for both lifting and topping the beets.

When the roots have been loosened by means of the plough, they are lifted and knocked together to remove as much as possible of the adhering soil; they are then laid in rows for topping. Topping consists of cutting the beet through at the line between the white skinned root and the greened crown which carries the foliage. As previously pointed out the whole of the greened portion should be removed, because if part is sent to the factory its manurial value is lost and it will be counted as part of the tare on the consignment.

It is best to harvest the last of the beets in November and to place in clamps that portion of the crop which has to be delivered at a later date. If beet is left in the ground as late as December the land is likely to be very wet and the harvesting operations are more difficult and costly.

Yield.—On light land that is not in a very high state of fertility 8 tons of washed beet per acre is considered a fair yield and 10 tons would be exceptionally good. On better and more fertile land, capable of yielding up to 25 tons of mangels, 10 to 12 tons of washed beet per acre can be got, while on the very best soils 15 tons per acre is sometimes exceeded. The sugar in British-grown beets generally runs from 17 to 18 per cent. of the weight of washed roots. The weight of the crowns and tops varies greatly but usually amounts to from 5 to 6 tons per acre.

Beet Diseases.

Beet is attacked by the same fungus diseases and insect pests that affect mangel, but there is no pest which is sufficiently serious to cause much damage unless the crop is grown for several years on the same land.

CHAPTER V

PULSE CROPS—BEANS

THE bean is one of the most ancient of cultivated plants. Although field beans are grown in most parts of Britain, it is in the south-eastern counties of England that they are cultivated to the greatest extent. The bean acreage in this country has decreased greatly, but this is largely because it is a crop suited to the very heaviest classes of soil, much of which has been put down to permanent grass owing to high costs of cultivation. As beans constitute the only highly nitrogenous food that can be grown in a great many localities, they are of great value for blending with starchy cereal grains in preparing well-balanced rations for stock, especially dairy cows. Cracked beans may be fed to horses, but bean meal is the most useful form for feeding purposes, and can be safely fed to pigs and calves as well as to cows. Although bean straw is somewhat coarse and unpalatable it is nevertheless highly nutritious, and when chaffed and mixed with other foods is a valuable addition to the rough fodder of the farm. Beans form an important constituent of many soiling and ensilage mixtures, and produce a very large bulk per acre when thickly sown and heavily manured.

Beans, however, have a number of disadvantages. In hot seasons the crop may be very severely attacked about the beginning of July by the Black Aphis, and although winter beans are less susceptible than the spring varieties they also are attacked in very bad years. When the whole crop is covered with aphides its yield is likely to be negligible, and it may be most profitable to make it into silage. Rooks are another common cause of serious damage. Wind frosts may injure the plants in March or April and blacken them to the ground, and beans that are sown early and become

"proud" in autumn may be affected in the same way. Frosted crops never recover properly and they leave bare patches of ground which tend to become foul with weeds. A badly damaged crop had better be ploughed in, though if the damage is slight it may be worth while to drill in a few bushels of peas or spring cereals in order to fill up the blanks. Beans cannot be grown on the same ground year after year, since they are liable to a disease akin to clover sickness. On the whole, a crop of beans allows the land to become rather dirty, and if drilling is carried out in rows wide enough apart to permit of horse-hoeing, a maximum yield cannot be expected.

Varieties.—The two main types of beans which are generally recognised are the winter and spring varieties. Winter beans, which will grow under relatively poor soil conditions, are sown in autumn and withstand fairly severe frost; they develop strong lateral branches, produce the largest yields of pulse and straw, and come to maturity much sooner than the spring sorts. Spring varieties resemble winter beans in appearance but are less hardy, and do not tiller or crop so well; they are very late in ripening, and if not sown early may fail entirely in a dry year. As is the case with wheat, the winter crop, because of its greater productiveness, is invariably preferred where it will stand the climate. If spring beans are grown, the earlier the seeding the greater and more certain the crop, provided that late frosts do no damage. The Scotch horse bean resembles the English winter varieties, and may be autumn sown in the more genial southern climate. The tick bean is a small round spring sort which has a large number of pods and crops well. Mazagan and Heligoland are also well known varieties.

The Cultivation of Beans.

Soil and Climate.—Beans are grown to a greater or less extent in most of the arable districts of Britain, but they give much the best results when grown on stiff clay soils, and may even fail on the lighter portions of a field. Probably

the very best soils are the chalky boulder clays, as the bean does best where there is plenty of lime; but the crop will not thrive unless the land be well drained. On land rich in humus, the yield of grain is often disappointing though the weight of straw may be very great. When once established on good soil the bean resists drought well, but because of its liability to suffer from frosts, the winter varieties are reliable only in the south.

Place in Rotation.—Beans may take the place of clover in a rotation, as, being legumes, they tend to increase the soil reserves of nitrogen. They may, however, be grown between two cereal crops in order to allow the land to be cleaned, and in such a case it is necessary to sow them in wide drills. In many clay land rotations beans are grown between two crops of wheat, and no particular trouble is taken to suppress the weeds that creep in; but such rotations usually contain a bare fallow, and, moreover, a dense crop of wheat has an excellent smothering effect, so that this practice does not make the land as foul as might be expected. The bean is one of the best crops to grow on broken-up grassland, as not only does it crop well on such a soil, but it is probably more resistant to wireworm and leather-jacket attacks than any other farm crop.

Preparation and Sowing.—Winter beans should be sown early, and most farmers like to get the operation over before the end of the second week of October. On rich land, September sown beans may develop too strongly before the cold weather sets in and consequently suffer from frost. On the other hand, sowing after the first of November should not be attempted, and it is better to wait and put in a spring variety. The usual autumn seeding is at the rate of $2\frac{1}{2}$ bushels (bushel = 63 lb.) per acre. Spring beans must be sown early, and once the beginning of February is reached the sooner the seed is in the ground the better. It is not always possible to get on the land as early as this, but at any rate the beans should be sown before any other spring crop, and a seeding of about $3\frac{1}{2}$ bushels per acre is necessary. As with many other crops, the methods of preparation and of

sowing depend on how the farmyard manure is applied, and, of course, whether autumn or spring sowing is to be adopted; but seeding may be carried out in any of the following ways:—

(1) The land may be deeply ploughed in autumn and left exposed to the weather throughout winter. In early spring the soil is cultivated and harrowed, and drawn up into 26-in. drills by means of a double mould-board plough. Farmyard manure is spread in the bottoms of the drills, and a special three row bean drill is employed to drop the seed on the top of the manure. The ridges are then split to cover the seed, and harrowed and rolled before the plants come through the ground. Beans grown in this way may be looked upon as a true fallow crop, as they permit of the thorough cultivation of the soil between the rows. But the suppression of weeds is never so successful as in the case of potatoes, because the smothering power of the crop is much less.

(2) In the West of Scotland beans are often broadcast on the ploughed grassland in February and harrowed in. About three weeks later a late variety of oats is broadcast at the rate of about 3 bushels per acre on the same land and harrowed in also. The name "mashlum" is given to this mixed crop; the object of sowing the two species at different dates is to secure that the different plants will be ready for cutting at the same time. After threshing the beans are separated from the oats by screening.

(3) Beans may be sown on the flat in rows about 20 in. apart by means of a grain-drill. This may be done either in autumn or in spring. The operations preceding drilling consist of ploughing, cultivating, and harrowing until a moderately fine tilth has been secured. This method will produce a large crop, but as horse-hoeing can only be carried out during the early stages of growth the land tends to become rather foul.

(4) Beans may be dibbled by hand. Long handled dibbles are used, and the beans planted in every second or third furrow slice on freshly-ploughed land, the land

being afterwards harrowed. With the present high cost of labour this method has little to recommend it.

(5) One of the cheapest and best methods of sowing is to plough beans in. Under ordinary circumstances a row is ploughed in under every second furrow, though every third furrow may be preferred where horse cultivations are likely to be required, the furrows being about 10 in. broad but not more than about 4 in. deep. This is done by attaching a small drill or hopper to every second or third plough as the case may be, the seeds being deposited in the open furrow and covered over by the next furrow slice. Seed put in in this way is left at a uniform depth and protected from the ravages of birds.

Manuring.—On most soils all the manuring that is necessary is about 10 tons of dung per acre; but when beans are grown after old grass no manure should be required. The crop has a high demand for lime and responds to phosphates and potash, but as it is leguminous will seldom give a return for nitrogenous top-dressings. It is found, however, that when beans are grown on a soil that has not carried the crop before, where the right kind of bacteria may be absent, the plants are unable to form nodules; it then becomes necessary to apply nitrate of soda or some such nitrogenous manure, or else to inoculate the soil. When no farmyard manure is available, good results may be got by harrowing in 4 cwt. of superphosphate and 1½ cwt. of muriate of potash per acre with the seed.

After Cultivation.—As soon as the land is sufficiently dry in March the beans should be harrowed. This tears out numbers of annual weeds and breaks up the caked surface of the soil, so that air gets access to the plant roots and growth is stimulated When further drying has taken place, horse-hoeing may be commenced and should be continued throughout the season as often as is practicable. The type of hoe employed will depend on the width between the drills. By far the most thorough cleaning can be carried out when the rows are far enough apart to admit of the use of one-row drill grubbers. However, three-row

horse-hoes will do good work in narrow drills before the plants become too tall. If the land does tend to become foul when the crop is ripening, a thorough scarifying of the stubble after harvest will do much to minimise the ill that has been wrought. When horse-hoeing is no longer possible, hand-hoeing should be carried out if labour can be spared.

Harvesting.—Winter beans are generally ready to cut about the beginning of August, but the spring varieties are very late and are seldom ripe until after the cereal cutting is over. The time of cutting has a very great influence on the feeding value of the straw; when cut in green condition bean straw is very little inferior to good hay, but if allowed to become dead ripe it is not only unpalatable but fibrous and innutritious. Moreover, late cutting gives rise to considerable loss through the beans "shelling" during harvest. If the crop is taken a little early, the only inconvenience will be a slight delay until it is dry enough to stack. The best way to judge the ripeness is to examine the scar (hilum) on the end of the bean where it is attached to the pod; cutting should commence whenever this has turned dark-coloured.

Cutting is most expeditiously carried out by means of a binder, but where the crop is short and there is a large number of pods near the ground the use of a reaper may result in a smaller proportion of loss. After cutting, the sheaves are stooked in the usual way, and stacked when they are dry. No crop while in the stook will withstand bad weather better than beans. They may be left in the field until the more susceptible white crops have been secured, and suffer no damage if they get a brisk shower while being carried. Because of the large number of pods exposed on the outside of a bean stack, many farmers carry the thatch right down to the ground in order to provide better protection.

New beans do not form a healthful food for stock and the crop is better left unthreshed until spring; indeed it is often kept for a year before being fed to stock. In

practically all cases the bean crop is the last on the farm to be threshed.

Yield.—The bushel weight of beans is about 63 lb., and the average yield about 4 qr. or 18 cwt. per acre. The average proportion of pulse and straw are 40 and 60 per cent. respectively, *i.e.* an ordinary crop will produce nearly a ton and a half of roughage.

PEAS.

The pea is a leguminous annual which is grown in the vicinity of most market centres, and on a field scale on many light chalk and limestone soils. Although peas may be roughly grouped into field and garden varieties, the methods of cultivation are much the same in both cases, and fields of certain garden peas are frequently grown on the farm. Early market garden peas are sown in sheltered spots in November and December, the hardiest round varieties being chosen for this purpose. Maincrops, which are required to produce a continuous supply of green peas throughout the summer months, are sown in successive lots during March, April, May, and June. On a commercial gardening or field scale the cost of staking the crop is prohibitive, and it is necessary to cultivate dwarf varieties which require no support; but the use of brushwood stakes for tall garden peas undoubtedly results in an increased yield and greatly improved quality.

Field peas differ from garden sorts in being smaller, hardier, stronger and shorter stemmed, and in having coloured instead of white flowers. The Prussian Blue, the Maple, the Dun, and the Common Grey are well-known varieties. White or blue peas may be used for either human or animal consumption, but those which have dark or mottled skins, being unattractive in appearance, have to be used for stock feeding only.

Like beans, peas are extremely valuable because their richness in protein makes them suitable for blending with starchy grains in the preparation of well-balanced rations. Peas may be sown with a cereal such as oats, and when the mixed crop is cut early it can be made into hay of

exceptionally high feeding value. Even after the crop has been ripened and threshed the straw forms good fodder which may be safely given to all classes of stock.

The Cultivation of Peas.

The best all-round pea soil is a light calcareous loam, but probably light sandy and gravelly soils are best when the crop is to be grown for the early market. On the other hand, maincrops do quite well on soil of moderately heavy texture. Although the pea does well in all parts of Britain, it is grown to the greatest extent in the eastern counties of England, probably because the soils are suitable and the dry climate reduces to a minimum the risks of bad harvests.

Most field peas are grown in districts where the Norfolk four-course rotation is in vogue, and it is usual to take the crop after barley and before wheat. On farms where clover sickness is troublesome, peas may replace clover in this way every alternate round of cropping. Although peas tend to leave the land dirty, they are harvested early, and it is possible to bastard-fallow the soil in preparation for wheat.

Peas thrive best on a stale furrow which has been worked down to a fine surface mould, and, after the autumn furrows have been weathered down during the winter, this tilth is prepared by cultivating and harrowing, as cross ploughing tends to leave the land too loose. The seed is drilled on the flat in rows about 14 inches apart at the rate of $1\frac{1}{2}$ to $1\frac{3}{4}$ cwt. (3 bushels) per acre, and the usual months for sowing are late February and March. Either after drilling or else when the plants are coming through the ground the land is rolled with an ordinary flat roller, and the crop is afterwards given a few light harrowings to check the development of weeds. Hand-hoeing may be practised early in the season, but is soon prevented by the plants spreading across the drills.

On the lightest soils the crop may be manured by ploughing in a light dressing of dung in autumn, but as a rule farmyard manure is unsatisfactory, as it promotes vegetative growth to such an extent that the peas become badly laid and difficult to harvest, and their quality may

be seriously damaged. Under garden conditions peas do best when grown without manure after a root crop which has been well fertilised, but under poorer field conditions it is customary to broadcast at seedtime about 3 cwt. of superphosphate and ¾ cwt. of sulphate or muriate of potash per acre.

When green peas are to be marketed, casual labourers are employed to strip off the pods and place them in bags or hampers. The uprooted and picked foliage is left to dry on the ground and afterwards carted off for fodder. When the crop is ripened for seed it is left until most of the pods are nicely filled and have lost their juiciness, and the stems have changed to a yellowish or brownish colour. Peas must not be allowed to become overripe or many of the pods will burst and loss will be occasioned through shelling. From the point of view of avoiding wastage the crop is best cut with a pea hook, but this method is very costly and is now seldom employed except where the crop is heavy and badly laid. Although peas cannot be cut with an ordinary mower (because the herbage gathers and clogs the knife) mowers with special cutter bars have been devised specially for pea harvesting, and give quite good results where the crop is moderately upstanding. When peas reach maturity their stems begin to decay at the surface of the ground, and it is often possible to break the plants over at this weak spot by employing an ordinary horse-rake. The rake is drawn at half its width through the crop, as far as possible at right angles to the general direction of the natural lodging of the plants. The bundles so formed are pulled away by workers using long-toothed gathering rakes for this purpose. A clear gangway is thus made for the horse on its return journey. The cut peas are put in small heaps or "wads" to dry and are turned every second day if the weather is favourable. As the condition of the herbage improves, the heaps are combined into larger ones, and are finally carted and stacked like hay.

A bushel of peas weighs about 63 lb., and a good average yield is about 30 bushels, or 17 cwt. per acre. The yield of straw is 20 to 25 cwt.

CHAPTER VI

FORAGE CROPS, SOILAGE, AND ENSILAGE—VETCHES

VETCHES or tares are leguminous plants which are very widely cultivated for forage purposes. A proportion must necessarily be ripened for seed, but practically all the produce so obtained is used for sowing purposes, the grain not being fed, like beans and peas, to stock. Tares may be grown alone or in mixture with other plants such as beans, oats, or rye; they may be soiled, made into silage or hay, or folded with sheep or pigs. The nitrogenous nature of the vetch makes it extremely valuable for feeding to stock, and its proper use obviates the necessity of purchasing expensive cakes and meals; but while it can be fed to all classes of stock with safety, it should not be supplied in excessive quantities when in a wet or succulent condition, as it is then very liable to cause hoven.

There are two common varieties, namely winter and spring tares, which differ little in appearance; and another sort known as the Gore which produces bigger seed and more bulky foliage. The winter vetch is hardy, and may be sown in autumn in the Midland and Southern counties, but it cannot always withstand the more severe winter climate of the north. Very often both winter and spring sorts are sown, and the dates of seeding so arranged as to produce an almost continuous supply of green fodder throughout the summer months. When the crop is cut early for hay or soiling, a certain amount of aftermath develops which is useful for grazing sheep or other stock, and winter tares may be cut in time to allow the farmer to sow a crop of turnips or plant cabbages on the same land. Spring vetches may be removed in plenty of time to allow of the preparation of the land for

wheat, and the crop is sometimes grown for ploughing under as a green manure.

Tares form a useful crop on all classes of land, but attain their greatest perfection on clay soils which are rich in lime. Their rich fibrous roots do much to improve the fertility and texture of poor, heavy land. For soiling purposes vetches may be grown throughout the full range of our climatic conditions, but no attempt should be made to grow seed or to make the herbage into hay except in early districts of low rainfall. Even in favourable localities ripening and drying are difficult to secure and the seed crop seldom gives complete satisfaction except in dry years.

Vetches may follow a white crop in the rotation, and although their habit of growth makes it impossible to suppress weeds by hoeing, they produce an excellent smothering effect, and leave the land much cleaner than either beans or peas. In Scotland small acreages of tares are often grown to supplement the pastures in the fall of the year, and pieces of land which are not cleared until late in spring—*e.g.* land on which potato pits have been situated—are frequently used for this purpose.

Winter vetches are usually sown in September and October. The seed may be broadcast at the rate of $1\frac{3}{4}$ cwt. (3 bushels) per acre on the ploughed land and harrowed in, or drilled at the rate of $1\frac{1}{2}$ cwt. ($2\frac{1}{2}$ bushels) per acre with an ordinary corn-drill on a bed that has been prepared by cultivating and harrowing. It is even possible, by drilling on stubbles which have been broken by cultivators, to avoid the cost of ploughing, but this is only satisfactory on particularly clean land. Spring tares may be sown in February, March, and April, and although later sowings may be carried out there is a risk of the plants being adversely affected by drought, and in all cases of late sowing a heavier seeding is necessary. Frequently, however, vetches are not sown alone but are grown along with other species. Owing to the great difficulty of securing seed crops in good condition, some farmers sow about a quarter of a bushel per acre along with beans. These give the tares plenty of support, and the troubles

associated with the lodging, moulding, and decay of heavy tare crops are altogether avoided. When threshing has been completed the seed of the two species may be separated by screening. A good mixed crop may be got by sowing 1 bushel of winter beans, $\frac{3}{4}$ of a bushel of winter vetches, and $1\frac{1}{2}$ bushels of winter oats per acre; but the most suitable proportions are determined by local soil and climatic conditions.

Although vetches are sometimes given light dressings of dung they respond best to phosphates, and potash is necessary on light soil only. A dressing of 4 cwt. of high grade slag, or an equivalent quantity of ground mineral phosphate, is all that is needed on heavy land. It should be applied with the seed. On light soil, 2 cwt. of steamed bone flour and $\frac{3}{4}$ cwt. of sulphate or muriate of potash will probably be more satisfactory. Superphosphates may be used on all soils that contain plenty of lime.

Winter tares grown either alone or with a cereal may be harrowed and rolled in spring, rolling being more important on soils that puff up under the influence of frost.

The time of cutting vetches will depend on the purpose for which the crop is grown. If the tares are intended for silage, cutting should take place when the lower pods are nicely filled but still soft. If required for hay, cutting should be delayed until the plants are a little more mature, because there is a loss of moisture in the ripening process, and up to a certain point this can be more safely effected when the crop is growing than when it is on the ground. If for seed, cutting should take place when the pods are filled and have lost their juiciness, and the colour of the foliage is changing to brown. When the crop is a mixed one and the vetches are supported by beans or a cereal, cutting may be performed with an ordinary mower. Cutting is most troublesome when the vetches are grown alone and ripened for seed as they frequently form a tangled mass which is badly laid, and although a mower may do the work when the points of its cutter bar are fitted with corn lifters, it is frequently necessary to cut the heaviest portions with

a scythe. When intended for soiling or ensilage, the green crop is often allowed to wilt for a few hours so that it will lose a proportion of its moisture before being carted. When hay or seed is required, the vetches are put in small heaps and treated in the same manner as a crop of peas. As tares are difficult to secure in perfectly dry condition and tend to become mouldy in the stack, it is often worth while to build small stacks round wooden tripods, which permit of a free circulation of air, an elevated situation where there is plenty of wind being chosen. Thatching should be done early as the herbage is very porous and does not run off the wet. The seed is separated in an ordinary thresher and the straw forms an excellent feeding roughage.

A moderately good crop of tares will yield 10 tons of green forage per acre. Green tares weigh well, but the moisture content is high, frequently exceeding 80 per cent. The bushel weight of the seed is about 64 lb., and a yield of 24 bushels or 14 cwt. is not often exceeded; the yield of threshed straw varies from 20 to 25 cwt. per acre.

LUCERNE.

Lucerne is a very valuable leguminous forage plant which is grown largely on the Continent of Europe and covers enormous tracts in North and South America. It is cultivated to a limited extent in this country, where it does not appear to have been given the attention it deserves, and is mainly confined to the south-eastern counties of England. Its roots penetrate suitable soils to great depths, rendering it practically immune from drought, and tapping sources of food which are seldom reached by other farm plants. The plant is a true perennial and when properly manured will continue to produce enormous crops year after year; but it cannot compete with weeds, and when grown on dirty land its productiveness gradually falls off until it has to be ploughed up. If, however, the land be properly prepared it can hold its own for six or seven years, and in this time, through the agency of the bacteria in its roots, it influences the

nitrogen reserves in the soil in such a way that the benefit can still be observed after many years of arable cropping.

Lucerne is often made into hay but it is usually cut green and used for soiling purposes. Three or four cuts may be made in a single season, yielding a total of anything up to 20 tons of forage per acre, and the cutting may be done at any time up to the flowering stage without the slightest danger of reducing the future cropping power of the plants. Lucerne may be grazed, but this always entails a certain amount of damage to the crowns of the plants, especially when close-cropping animals like sheep are employed. The herbage is best fed in a wilted condition and can be given to all classes of stock; pigs that are kept in confinement are fond of it and benefit by it greatly. Lucerne can be sown on land intended for poultry runs, as it has a much greater carrying capacity than grass, and its higher protein content makes it a more valuable food. The crop may be made into hay, and will produce as much as 4 tons of good dry forage per acre. It is unsatisfactory when used alone for silage, as, like other pure leguminous crops, it is too nitrogenous and tends to develop a bad flavour when fermented; but if fed into the cutter with an equal quantity of green oats, this disadvantage is obviated.

Lucerne thrives best on a deep, calcareous loam overlying a pervious subsoil, because under these conditions it can obtain the complete freedom from acidity which is so necessary for its healthy growth, and its roots can attain their best development. It grows, however, on practically all soils that are properly drained, and it is only on wet and sour land that its cultivation should not be attempted. The warm and somewhat dry southern counties are most suitable, as many of the common varieties have difficulty in withstanding the cold climate of the north and the heavy rainfall of the west. Another adverse factor to the growth of the crop is the absence from most British soils of the strain of *B. radicicola* which normally inhabits lucerne roots. An immense number of lucerne varieties are known, and

although some strains of seed from abroad have been grown with very satisfactory results, little has so far been done to secure the best sorts for this country. The plant does not ripen seed satisfactorily in Britain.

As lucerne is sown down for several years it follows that it does not occupy a regular place in the rotation, but is grown as a substitute for other forage crops or meadow-hay.

By far the most important point in the preparation of the soil for lucerne is the thorough eradication of weeds. The necessity for thorough cleaning of the land cannot be over-emphasised; the crop will certainly be a failure if it has to compete with weeds. Lucerne will well repay a thorough preparation, and it may be worth while to grow two successive root crops, or to give the land a bare fallow to get it clean. Lucerne may be sown with or without a nurse-crop; it may be broadcast or drilled, and it may be seeded in late April or in early August. The nurse-crop may be a cereal such as oats or barley, or a green crop such as rape or mustard. But whatever crop is employed it is important that its seeding should be thin; the bad reputation which cereals have as nurse-crops for lucerne can nearly always be traced to the error of giving a normal seeding, which naturally produces a full crop, with the result of a smothering effect. When sown with 3 or 4 lb. of rape per acre, the lucerne will have more room to develop and just sufficient protective shade from sun and wind; it will grow more quickly, and will produce a small crop fit for mowing towards the end of its first summer. In a favourable season the quickest development takes place when the crop is sown alone; but the disadvantages of this method are the lack of protection in hot, dry springs, and the loss of the cereal crop which may go far towards defraying the expense of seeding. Lucerne may be drilled at the rate of 25 lb. of seed per acre in rows about 9 to 12 in. apart, or broadcast on the flat at the rate of 30 lb. per acre. In some cases a satisfactory stand has been obtained with as small a seeding as 15 lb. per acre. The object of drilling is to enable the land to be hoed and the weeds suppressed,

particularly during the first season when the growth is slow; but as these operations are very costly, and have to be done continuously if they are to be effective, the drilling may be less economical than broadcasting at a sufficiently thick rate to cover the ground well and to leave few spaces in which weeds can develop. A broadcast crop can be given severe surface treatment with harrows for the suppression of weeds with little risk of damage to the plants. As August is usually a wet month, sowing at that time reduces the risk of damage to the young plants by drought. As lucerne does not form a close bottom some farmers sow it in mixture with about 10 lb. of grass seed, so that the ground will be covered and weeds will have less chance to develop; but specially heavy crops cannot be obtained when this is done.

The manuring which generally gives the best results is about 4 cwt. of superphosphate, or an equivalent of some other phosphatic manure, and 3 cwt. of 20 per cent. potash salts applied to the land before seeding. Sometimes small dressings of nitrogenous fertilisers are effective in giving the young plants a better start. When heavy crops are removed each year it is essential that mineral dressings should be repeated in order to maintain the fertility of the soil. If the soil is short of lime, heavy dressings should be applied before any attempt is made to grow this crop. Very often the slow development and the pale colour of a crop of lucerne can be traced to the absence of the proper nitrogen fixing bacteria, and the old remedy for this was to obtain soil from a field that had grown lucerne well and to scatter it over the crop at the rate of a few hundredweight per acre. The modern treatment is to inoculate seed with the correct strain of micro-organism, and this should always be done when growing the crop for the first time. In many experiments such inoculation has doubled the yield and at the same time has enormously increased the protein content of the foliage. The cultures for the treatment of the seed can be obtained through most agricultural colleges.

The permanence of lucerne depends to a great extent

on the cleanness of the land at the time of seeding, and on the success of the operations for the control of weeds during the early growth of the crop.

SAINFOIN.

Sainfoin is a leguminous plant which is of great importance in the sheep districts of the south of England. It may be used for soiling purposes, but it is usually grown for hay or grazing. It is often used as a substitute for clover on land where clover-sickness is prevalent, and it forms such a healthful food that sainfoin leas are frequently used as pasturage for sick or weakly animals. It produces stems about 20 in. high, is deep rooted like lucerne, and forms strong rosettes of basal leaves which withstand hard grazing.

There are two distinct varieties, namely Common and Giant sainfoin. Common sainfoin is a perennial which reaches its maximum development in about three years, and is used to sow down leas for six or seven years' duration; it is best utilised for grazing as it produces very little aftermath when mown; it grows more slowly and produces less bulk than the Giant variety, and, like lucerne, it has ultimately to be ploughed up as it becomes very weedy. Giant sainfoin is shorter lived than the common variety, and is cultivated as a rotation legume in place of clover; it establishes itself quickly, produces good bulk, and as it flowers early and grows vigorously after cutting, it will produce at least two crops of hay in a season.

Sainfoin is most largely grown on the dry, chalky soils in the neighbourhood of the Downs. As it is deep rooted and drought resisting it thrives on light land, but it will only grow where the climate is warm, and fails utterly unless the soil is well drained.

The commoner sort of commercial "seed" of sainfoin is really a fruit which contains a true seed within a light and spiny husk; it is bulky, and owing to its lightness is very difficult to harrow into the soil. However, it is possible to obtain true seeds which have had their husks removed by milling, and these are more easily handled. The land should

be in a clean condition before sainfoin is grown, and the crop should be seeded under a nurse-crop of barley by broadcasting or drilling at any time from early March to late April. About 56 lb. of milled seed is required per acre, but the seeding has to be increased to 120 lb. when rough seed is used. It is usual to drill the seed in rows about 10 in. apart, and in a direction at right angles to the rows of barley.

A good manuring per acre is 3 cwt. of superphosphate and $\frac{3}{4}$ cwt. of muriate of potash applied with the seed; but where Common sainfoin is down for several years, and a crop of hay is removed each season, further dressings of phosphates and potash will be necessary to prevent rapid deterioration. Short dung is sometimes employed but this can generally be more usefully applied to a root crop.

Although a crop of seed may be taken from sainfoin before it is broken up, the production of seed in the early years of the lea so lowers the vitality of the plants that many of them die out. Consequently good management demands that the plants should either be kept well grazed, or mown as soon as flowering begins.

When sainfoin is made into hay it is cut at the commencement of flowering, and very carefully handled in order to avoid breaking off the delicate leaves. Turning can be most safely carried out in early morning when there is dew on the herbage. 30 cwt. of hay is about the average yield.

TRIFOLIUM.

Crimson or Scarlet clover, generally known as Trifolium (*Trifolium incarnatum*) is an annual legume which finds a useful place in the agriculture of the south of England for catch-cropping purposes. It establishes itself very quickly, and produces a fair bulk of nutritious fodder which may be either grazed or soiled, but it develops practically no second growth. The chief disadvantage of the crop is that it is dangerous food for stock when it is overripe, for it produces very hairy flowers which may form balls in the intestines and cause death.

Crimson clover is successful only in the warmest English counties as it cannot survive a very cold winter; it thrives on light, firmly compacted soils. Trifolium is practically always grown as a catch-crop after a cereal has been harvested, and it is consumed in the spring in time to have the land clear for turnip sowing in June. It cannot be sown under a nurse-crop in spring like most other leguminous forage crops, as it will not grow again after being cut at harvest.

Sowing takes place on a stubble which has been worked into a fine surface mould without ploughing. The plant thrives much better on a firm bottom of this kind than on land which has been ploughed. The seed is broadcast at the rate of 20 lb. per acre as early in August as possible, and harrowed in. If there is rain the plants grow quickly and are firmly established before winter sets in, and if early, medium, and late varieties are sown the crop will provide a continuous supply of forage in May and June. Trifolium is too hairy and fibrous to make satisfactory hay. Some varieties possess white flowers.

CABBAGES.

The cabbage is a cruciferous forage plant, which, along with Broccoli, Brussels sprouts, and many allied species, has been obtained by a long process of selection from the wild cabbage, *Brassica oleracea*. It is one of the most important forage crops cultivated in this country, and is grown to a greater or less extent in almost all arable farming districts. Cabbages may be safely fed to all classes of stock, and being mild in flavour do not taint milk unless fed in very large quantities; they are useful as green food for pigs and poultry, and are largely used when cattle and sheep have to be maintained in show condition; they may be folded with sheep and are superior to turnips and mangels in feeding value, and if suitable varieties are grown they may be sold for human consumption. A great advantage of the cabbage is that it can be safely fed whether mature or immature. If the stems and basal leaves are left in the ground when the crop is cut, fresh leaves and buds will form and will provide

a further supply of food suitable for sheep. Cabbages have the disadvantage that they cannot be harvested and stored like roots, and the flat-topped varieties are susceptible to a certain amount of decay if left standing for prolonged periods of wet weather. In late summer pasture grass deteriorates greatly in yield and nutritive value, and cabbages may be most usefully employed as a supplementary feed for stock during this period.

Varieties.—Cabbage varieties differ in appearance, size, hardiness, and the time required for their development. Although cattle cabbages are coarser than the ordinary garden sorts there is no hard-and-fast distinction between the two types, and garden varieties are frequently grown on a field scale. Cabbage varieties are very numerous, but they may be roughly grouped in the following way:—

1. *Late or Maincrop Varieties.*—These are large cabbages which require a long time to reach their full size—in some cases a year—and may be set in wide drills at yard intervals so that they have plenty of room in which to develop. They produce the largest crops but are somewhat coarse and suited for stock feeding only. The seed is sown in a bed about the beginning of August, and the plants are either dibbled out in October or left in the seed-beds over winter and planted in April. When the cabbages are set out in autumn a number should be ready for cutting about the end of July, but the plants may stand in the field until Christmas if necessary. If planting is held over until spring, however, growth will be somewhat retarded and little of the crop will be ready before September. Sometimes maincrops are sown in March for planting in April and May. When this is done it is better to set the plants closer—say 2½ ft. each way—as they do not have time to attain their full size; they will be ready for consumption in October. Drumheads, Ox-hearts, and Cattle-Savoys belong to this class.

2. *Autumn-sown Early Varieties.* — Early varieties are often sown in August and planted out in October with the object of supplying the spring cabbage trade. They are usually planted close. Alternate plants may be removed in

March or April, the remainder being cut and sold as soon as they are well hearted. Suitable sorts for this purpose are Sutton's April, Flowers of Spring, and Enfield Market.

3. *Spring-sown Early Varieties.*—These may be sown in March and planted out in April and May. Being early they will be ready for cutting or feeding in August, and as they are comparatively small they may be spaced 1 ft. 6 in. to 2 ft. each way. Sometimes early cabbages are planted in July after a forage crop that has been removed in June, and for this purpose the seed should be sown in May. The most forward plants will be ready for use in October, and the remainder may stand out until the end of the year. Early Drumheads and Winningstadts are suitable varieties in this class.

Although approximate dates of sowing, planting, and harvesting certain varieties are mentioned above, it should be remembered that much depends on local conditions, and the custom of the district had better be followed until experience of the crop has been gained. Cabbages are irregular in the time taken to reach their full size, and it is generally most profitable to cut the best plants and allow the smaller ones further time to develop.

Cultivation.

Soil and Climate.—The cabbage is a typical heavy land crop and attains its greatest perfection on strong clays that contain plenty of lime. However, it grows well on light soils which have been given body by dunging. The crop thrives anywhere in Britain and resists drought when once it is well established; but it does not start well unless it gets a good deal of rain, and in a dry climate is less resistant to parasites.

Place in Rotation.—Cabbages occupy the same place as roots in the rotation, and replace turnips for early feeding in districts where the mangel is the staple root crop. When planted regularly and wide apart, cabbages offer even greater facilities for cleaning the land than do roots. Planting may

be so done as to allow horse-hoeing in two or three directions, and hand labour is thus reduced to a minimum.

Preparation and Planting.—The most important sowing takes place in August; seeding earlier than this often results in a proportion of the plants bolting. A piece of good land in a sheltered spot is selected for the bed, and the soil is reduced to a fine tilth by ploughing and harrowing. In order to stimulate the growth of the young plants, about 3 cwt. of superphosphate may be applied and the seed is broadcast at the rate of 20 lb. per acre. The whole should be well harrowed in and then rolled. An acre bed will grow enough cabbages to plant about 20 acres in the field, the exact number of plants required being of course determined by the intervals of planting. If the raising of plants cannot conveniently be carried out, cabbages of suitable size may be purchased from farmers who specialise in this business. Cabbages may be sown with a drill like an ordinary root crop at the rate of 4 lb. of seed per acre; but this is seldom done as the plants get a later start, and the cost of singling is as much as the cost of dibbling.

The ground is prepared in exactly the same way as for root crops, and the cabbages may be planted in any of the following ways:—

(1) The field may be drawn up into ridges 24 to 30 in. wide in the same manner as when preparing for roots, and the plants dibbled in along the ridge tops. When dibbling young cabbages care should be taken not to bend the tap-roots, and the plants should be buried so that the leaf bases are covered, as this gives them a much stronger hold in the soil. Moreover, damp weather should be chosen for planting, and in a garden water should be used and the plants set in plenty of "puddle." The plants should be "heeled" so that the soil is pressed firmly about their roots.

(2) On free draining soils which are used for growing spring cabbages, the plants may be set along the bottom of shallow furrows which are opened by a double mould-board plough. The object of this is to provide shelter from frosty winds.

(3) When cabbages have to be planted in dry spring or summer weather, good results may be got by dibbling the plants into the middle of freshly turned furrow-slices. The object of following the plough closely in this way is to set the plants in the dampest and firmest portions of the soil.

(4) Cabbages may be laid by hand along the side of every third furrow-slice, so that their roots are covered by the soil turned over by the next plough. This is a quick method, but as the soil is not firmly pressed about the plant roots it is not very satisfactory in dry weather.

(5) Cabbages may be planted on the flat after the soil has been ploughed, cultivated, harrowed, and rolled. Before this takes place the land must be marked off, and this can be done with a seed-drill which has its coulters set to the desired intervals. If the marker is taken across the field in two directions, the one at right angles to the other, it becomes possible to space out the plants so accurately that horse-hoeing can be carried out in both directions, and very thorough cleaning effected.

As with practically all other crops, the optimum area for each plant depends not only on the variety but on the quality of the soil; wider spacing will be required on richer land. In almost every case early planting produces a distinct improvement in the yield.

Manuring.—As cabbages have a long growing season and are capable of producing an enormous weight of dry matter per acre, they should be manured with great liberality. The crop is sometimes said to be a gross feeder, but this must be reckoned as a point in its favour; its capacity for responding to fertilisers fits it for the most intensive types of farming. Farmyard manure is the basis of all dressings and may be ploughed in at the rate of from 15 to 25 tons per acre. On heavy land, 2 cwt. of superphosphate, 2 cwt. of steamed bone flour, and $\frac{3}{4}$ cwt. of sulphate of ammonia may be applied at planting time; in addition 2 or 3 cwt. of nitrate of soda applied in two or three dressings during the growing season will prove beneficial. On light land 1 cwt. of sulphate of potash may be applied in addition to

the above dressings, except, perhaps, where very large dressings of dung have been given. It pays to apply the nitrogenous top-dressing to cabbages by hand, and this is done by dropping a little of the fertiliser around the stem of each plant. Broadcasting may of course be practised, but owing to the wide spacing of the plants, much of the manure applied in this way never reaches the roots and is lost.

The subsequent management of the crop consists in the usual horse and hand cleaning operations, and in filling any blanks that may occur by means of seedlings which should have been retained in a bed for this purpose.

Securing the Crop.—Many attempts have been made to store cabbages and retain them for late use, but the methods are too costly to be worth consideration, and the practice cannot be recommended. The crop is best left in the field until it is needed for stock, and the plants should then be cut so that the large bottom leaves remain on the stem. This method of cutting retains a number of buds which will sprout and provide a very useful bite for sheep later in the season. If decay is to be avoided an endeavour should be made to have the crop used up before the end of the year.

On good land there is no difficulty in growing 30 to 40 tons of cabbages per acre.

RAPE.

Although rape is largely grown on the Continent for its seed, it is cultivated in this country mostly for forage purposes and generally as a catch-crop. Rape is closely related to the turnip, and can in fact be looked upon as a turnip without a root store; some varieties have leaves like swedes and others resemble turnips proper. In the south the crop is liable to suffer from mildew when sown early, and it is most popular in the damp and cool districts of the north and north-west. It may be cut for soiling, but is more usually folded with sheep, and it is sometimes used as a nurse-crop for grass seeds where cereals are unsatisfactory for this purpose.

Rape is usually broadcast at the rate of 10 to 12 lb. of seed per acre, but if drilled in rows 10 or 12 in. wide 3 or 4 lb. less seed will suffice. The highest yields are obtained when rape is drilled and singled; but the extra return does not justify the cost, and if a large forage crop of this kind is wanted, kale will generally be much more satisfactory. Sowing may take place at any time from May to late summer, and as the crop is second only to mustard in the rate at which it attains maturity, it may be grown after any crop that has been consumed in the spring. It is particularly useful if the land cannot be got ready in time to sow turnips.

Under average conditions a yield of 10 tons per acre may be obtained.

KALE.

Kale belongs to the cabbage tribe, and is for all practical purposes a tall growing cabbage with spreading foliage which forms no heart. The plant is susceptible to the various cabbage parasites, but resists many of the blights which affect turnips and rapes. It withstands bad winter conditions better than the cabbage, because its open leaves do not permit of the lodgment of moisture which would ultimately result in decay, hence it may be allowed to stand out until spring. Kale may be soiled for cattle or pigs or folded with sheep; it contains a high proportion of dry matter and is a very healthful food. As it grows readily after it has been eaten down, it may be fed off two or three times in a season. It does not grow as quickly as rape and is less useful for catch-cropping.

Thousand-headed kale and Marrow-stem kale are the best known varieties, the latter being thicker in the stem, taller and more responsive to rich soil and favourable climate; but grown side by side on poor to average land the two sorts are very similar. The seed is usually sown in April at the rate of 4 lb. per acre in drills 18 or 20 in. apart, and the plants are singled to intervals of 10 to 12 in. It should be remembered that the plants grow to a large size, and if broadcasting is carried out on any but the

poorest of land no more than 5 lb. of seed should be employed. Kale should be manured in the same way as cabbages, and is quite as capable of responding to liberal treatment. The spring-sown crop will be ready to feed in autumn and early winter; but if forage is particularly required for spring use in the following year, a hardy Thousand-headed variety can be sown about the beginning of August. Kale can easily be made to yield 30 to 40 tons of forage per acre.

MUSTARD.

White Mustard is a cruciferous annual which is commonly grown as a catch-crop. It may be used for green manuring or folding with sheep, and it has a high reputation for "flushing" ewes. Its most valuable characteristic is its very rapid growth; on good land it may attain a height of over 2 ft. in less than a couple of months. It is often grown after a crop of early potatoes, and is useful for conserving the residues of the heavy dressings of manure applied to this crop.

The seed may either be broadcast at the rate of 20 lb. per acre or sown in 12-in. drills at the rate of 15 lb., and seeding may take place at any time between early spring and the month of August. However, if the crop is to be eaten off it must be consumed before winter, as the plants are not sufficiently hardy to withstand frost. When mustard is grown for green-manuring, and the plants are tall, it is necessary to attach a drag-weight and chain to the plough in order to roll the long material under the furrow.

Black Mustard.—This plant is specifically different from white mustard. It is not cultivated as a forage crop, but is commonly grown in Lincolnshire, Cambridgeshire, and Norfolk for its seed. It is generally grown on contract for the manufacture of condiment. Although ripening a crop of this kind generally tends to leave the land foul, the shed seed can usually be made to germinate by harrowing the stubbles, and the plants are then killed by ploughing.

SOILAGE.

Soilage is the practice of feeding animals on cut green forage. In an extreme case the stock may be kept in confinement throughout the year; in other cases forage crops may be cut and used to supplement the pasturage at the beginning and end of the grass season only. The advantage of soiling stock is associated with the superior productiveness of arable as compared with grass land, and a properly designed soilage system enables a larger head of stock to be carried on a given acreage.

Advantages of Soilage.—The advantages of soilage over the ordinary method of keeping stock on mixed arable and grass farms are as follows:—

(1) When a plant is kept closely grazed its leaf surfaces are reduced to a minimum and its power of synthesising foodstuffs is diminished to a corresponding degree. On the other hand when a plant is allowed to grow to the verge of maturity it is capable of making the most of soil and sunlight, and becomes a highly efficient food-producing organism. When a plant is cut once or twice only during the season its yield for the year and its stock-feeding capacity are greater than when it is kept short by grazing.

(2) With many farm crops the longevity of a species is opposed to its productiveness, *e.g.*, Giant sainfoin is a heavier cropper than the perennial Common variety. Under arable conditions it is possible to select the most productive species, and the length of life is immaterial provided that one good crop can be obtained. For permanent pasture, however, the selection of lasting species is essential even if they are relatively poor producers.

(3) Weeds can be better controlled under arable conditions, while the partial suppression of good forage plants by useless indigenous species can hardly be avoided in grassland.

(4) The plants are not damaged by being trampled and broken by stock nor fouled by manure.

(5) In hot weather and during the "fly" season, when

so many animals lose condition, stock may be comfortably housed so that they go on producing substantial gains, and there is no falling-off in the milk yield of cows. In wet or cold weather the advantages of protection are equally obvious.

(6) It is possible to cultivate a bigger proportion of the land by doing away with such expensive structures as fences and other field boundaries, and the removal of these shelters for weeds and vermin results in bigger and cleaner crops. There is no need to have watering-places all over the farm.

(7) With a well-arranged sequence of soiling crops the animals receive abundant and suitable fodder all the year round, and neither milk production nor live weight increase is affected by drought, or by the reduced feeding value of pasture towards the end of summer.

Disadvantages of Soilage.—In order to understand soilage as an economic proposition its merits should be compared with its chief disadvantages, which are as follows:—

(1) More labour is required not only for feeding the stock but for the intensive arable farming necessary for the production of a sequence of forage crops throughout the year.

(2) In order to justify this extra labour, a very large head of stock must be carried on the farm, and this requires extra capital and accommodation.

(3) The sequence of crops required for feeding the animals necessitates periodical seedings during the greater part of the year, and long periods of wet or dry weather may so seriously interfere with these operations that one or more of the crops is missed, and a food shortage may result. Moreover, when crops are seeded at odd times the ravages of birds assume a serious aspect, since when no other sowing is going on in the district these creatures give the seed their undivided attention.

(4) The forage must be cut daily in order to avoid losses through fermentation and moulding, and this is difficult to carry out in bad weather.

(5) When crops are grown in close sequence the soil is liable to become very dry, and in localities of low rainfall this results in difficulty in getting the seed to germinate, and in diminished yields.

Having considered the advantages and disadvantages of soilage, under what conditions is the soiling of stock likely to be practicable in this country? Under most systems of mixed farming a certain amount of soiling is well worth while, particularly for the production of fodder in early spring when roots are badly decayed and grass is producing little growth, and, again, in autumn when the pastures begin to fail and the root crops are insufficiently mature for safe feeding. But specially suitable conditions are necessary if stock is to be maintained on the produce of arable land only. It is for cattle and particularly dairy cows that soilage has its greatest usefulness, and because the cow is the most efficient producer of human food, it is better adapted for intensive management than any other animal. What then are the conditions which enable cow-keeping to be carried on profitably by means of soilage?[1] The soil should be good and capable of responding to heavy dressings of manure, otherwise it will not pay under intensive cultivation; moreover, it should be light in texture so that it can be worked at practically any time of the year, and carted over during wet weather without fear of puddling. The rainfall must be fairly high and evenly distributed, otherwise there will be no assurance of germination of summer-sown crops, which are an essential part of the system. The farm should be in the proximity of a good market, so that high prices may be obtained for milk and the returns may be commensurate with the high labour costs. The system adopted should include a variety of leguminous crops which, by taking the

[1] Although systems have been worked out for the maintenance of stock throughout the whole year on the produce of arable land, practical trials have shown that the present economic conditions throughout the greater part of the country are unfavourable to the success of these schemes. Success is most likely to be attained where high rents give justification for intensive methods, and where labour is cheap.

place of expensive nitrogenous cakes, will enable feeding costs to be reduced.

For the maintenance of stock by soilage a succession of crops must be cultivated so that there may be a continuous supply of forage throughout the summer. The necessary rotation can be worked out only from a knowledge of the times of sowing, periods of ripening, and yields of the various forage crops. It may be best to begin in a simple way with rye for early spring use, winter oats and vetches for late spring, spring oats and vetches for summer, and cabbages for autumn; a complete rotation may be developed as experience of these crops is gained under local conditions.

ENSILAGE.

Ensilage is the name given to a process whereby green fodder is preserved in a succulent condition in order that it may be consumed in winter or at any time, and silage is the term applied to the material when ready for use. As a rule silage is made and preserved in a structure called a silo, but it can also be made in a stack or pit. Ensilage was not considered seriously in this country until about 1882, when continuous wet seasons made farmers look round for a new method of preserving their hay crops. But owing to lack of knowledge and the utilisation of unsuitable buildings, the early efforts were not very successful, and it is only within the last twenty years that ensilage has made much progress in Britain.

Principles of Preservation.—In order to make good, palatable silage without undue loss, it is essential that one should understand the principles which underlie the preservation of the forage, and the nature of the fermentation by which the changes are accomplished. Fermentation results in a loss of from 5 to 15 per cent. of the dry matter of the crop; but this must be looked upon as an unavoidable manufacturing waste, and, after all, it is no more than is occasioned in the making of hay.

When fresh green fodder is thrown into a silo it at once begins to ferment and the temperature rises. This heating

is brought about by the respiration of the living cells, the action of the plant enzymes, and the activities of the micro-organisms introduced with the crop. Fermentation is retarded by lack of air, and is brought to a stop either by the accumulation of compounds which prevent further bacterial activity, or by the attainment of a temperature which kills the organisms. In the first changes oxygen is absorbed from the interstices of the mass and replaced by carbon dioxide, which renders life impossible except for bacteria which can obtain energy by breaking down compounds in the surrounding material. Such bacteria are present, however, and in order to get energy they change the plant sugars into lactic and other acids, and provided the temperature does not go too high they continue this process until they have produced a concentration of acid which inhibits their further action. The acid acts as a preservative and, provided that air is excluded, checks all other bacterial activities, including putrefaction. The bad flavours which may develop in silage made from a purely leguminous crop arise from the lack of enough sugar to give the adequate amount of acid. The main factors in the preservation of the forage are therefore the development of acid and the exclusion of air.

The ultimate quality and appearance of the material is largely determined by the nature of the initial fermentation. Both oxidation and the conversion of sugars into acids go on in all silage, but when the cut forage is damp and well compacted very little air is included and the amount of oxidation is negligible. Thus at one extreme there is a typically acid silage which is produced with a minimum loss of dry matter due to fermentation, and in which the temperature may not have risen much above 90° F.; it is generally brownish in colour and possesses a clean acid taste; it is relished by stock and has a high feeding value. If forage is ensiled in a moist condition, it may contain so much sap that when under pressure in the silo it loses a good deal of juice containing valuable nutritive materials. Nevertheless acid silage can be made without wastage

provided the crop is reasonably mature or slightly wilted and the necessary exclusion of air is secured by thorough compaction. Immature crops are relatively rich in organic nitrogenous compounds, and if they are ensiled they may undergo both putrefaction and butyric acid fermentation. If forage is both immature and wet when put in a silo it is therefore liable to become rancid and objectionable unless special precautions are taken in its management (see "Filling the Silo").

Workers at Cambridge have referred to a "green fruity" type of acid silage which is formed when moderately mature yet sappy forage is fed into the silo directly after cutting. The type appears to be uncommon, and although it is very digestible it has the disadvantage that the conditions for its formation lead to an excessive loss of juice from the silo and involve some risk of butyric fermentation.

It is obvious that the moisture content and the degree of compaction of the ensiled crop cannot be very accurately controlled, and in practice sufficient air is often included to cause a good deal of oxidation. Up to a point this aerobic fermentation does not result in serious loss of nutritive matter, but it may nevertheless prevent the material from acquiring a strong acid flavour and cause it to assume the characteristics of what is termed sweet silage. It is unreasonable to draw a hard-and-fast line between the acid and the sweet types of silage, for even sweet silage contains acid. The "sweetness" is merely an indication of the degree of air fermentation which has gone on in the silo, and many samples are no nearer to the one type than to the other. On the whole, however, acid silage is preferable to sweet as it is less wasteful and more digestible.

When a rather dry and mature crop is ensiled, or when small amounts of material are put in the silo at considerable intervals, fermentation is very active and the temperature may rise to over 160° F., with the result that there is serious loss of dry matter and the proteins may be made relatively indigestible. In an extreme case of this kind so much air may be present that the contents of the silo become mouldy or musty.

In an ordinary silo there is a tendency for the material at the top to be overheated owing to the close proximity of the air; the middle portions are usually sweet, and the bottom herbage which is under great pressure is generally acid.

The Nature and Uses of Silage.—To what use can silage be put in the economy of the farm? It is generally considered that live stock on winter keep thrive best and make the most of their rations when supplied with a proportion of succulent food, and, ordinarily, roots are employed for this purpose. Can silage replace roots for winter feeding? Although silage is a succulent food, and as such tends to stimulate the appetite, its composition must necessarily be much the same as that of dry fodder such as hay, but with a larger proportion of moisture. Roots, on the other hand, differ from fibrous herbage in being more of the nature of dilute concentrates, that is the proportion of digestible to indigestible dry matter is high, and the gross food value is low only because of the high water content. It would appear, then, that from the point of view of composition silage can replace hay and water, or roots and straw, but that it cannot be regarded as a simple substitute for roots. However, the daily ration of roots, for, say, cows, varies from 30 to 100 lb. under different farming conditions, more hay being fed where roots are few, and if the other constituents of the ration are properly balanced, the milk yield does not appear to be affected. Therefore, leaving out cost for the moment, it would appear that silage might well be substituted for hay, and a good portion of the roots fed to cattle. This substitution has been successfully carried out in feeding both cows and bullocks; but attempts to dispense with roots entirely have not always met with success.

From the economic aspect silage may be used to replace hay if it can be produced, dry matter for dry matter, at a cheaper rate, and may be employed to replace roots to a considerable extent. The utility of ensilage in British farming depends on the relative costs of producing silage and certain other crops, and these costs are determined by

the climate and the nature of the soil. Roots cost most to grow on the heavy classes of land such as the London clays, where, moreover, the rainfall is insufficient to enable roots to develop a large yield, and the cost per ton is correspondingly increased. The profitable cultivation of hay depends largely on getting dry weather during the hay-making season. It is therefore where a damp climate renders the hay crop uncertain, and where intractable soil and drought militate against the economical cultivation of roots, that the practice of ensilage is likely to be profitable.

The question of the utility of ensilage resolves itself into a comparison with hay and roots, and under British conditions ensilage may have the following advantages: (1) Silage can be fed without risk to horses, cattle, sheep, and pigs; there need be no waiting until it has matured, and, once the initial fermentation has ceased, keeping it for prolonged periods does not lead to further loss. (2) As the crops from which silage is made are usually autumn sown, there is little chance of the young plants being checked by drought, and if damage should take place a spring crop may yet be sown. (3) The carting of the crop takes place during the dry summer months, and there is little danger of puddling the soil and doing damage; moreover, the forage is removed from the land in plenty of time to enable a catch-crop to be taken. (4) Wet weather is no great hindrance to silo filling though it makes the curing of hay impossible, and there is a much smaller loss of dry matter in making silage than is occasioned to hay by a few falls of rain. (5) The presence of a silo makes it possible to save residues of crops which have been damaged by blights, and which would otherwise have to be ploughed in. (6) The labour of making silage is less than that involved in the cultivation of roots on heavy land, or in making hay in a bad season.

The chief drawback to a more general adoption of ensilage is the heavy capital expenditure involved in the erection of a silo and the provision of the necessary chaffing and blowing apparatus.

Crops for Ensilage.—The most popular crop for making

into silage in Britain is a mixture of oats, beans, and vetches. A crop of this kind produces a heavy yield per acre, is sufficiently nitrogenous to have a high feeding value, can be cultivated and handled cheaply, and can be grown with certainty in any part of the country. It is impossible to prescribe a mixture which will suit all conditions, but 2 bushels of winter oats, 1 bushel of winter beans, and 1 bushel of winter vetches per acre have given satisfactory crops under average conditions; if the proportion of beans is increased where the land is heavy, and more vetches are used when the soil is light, no great mistake will be made to begin with, and a better mixture may be prepared after a year or two's experience. Naturally, a heavier seeding will be required for spring sowing, or in growing the crop in a cold or elevated region. The ideal time for cutting a crop of this kind is when the lower pods are well filled and the oats have reached the milk stage.

As previously mentioned, pure leguminous crops are not satisfactory as they tend to become tainted in the silo, but there is no reason why fairly mature peas, vetches, lucerne, sainfoin, or clover should not be used if mixed with a proportion of green cereal at the time of filling. Mixtures of clover and grass may be made into silage, but their yield is too small to justify their cultivation specially for this purpose. Attempts to convert cabbages, kale, and other cruciferous plants into silage have been unsatisfactory, though objections to their use may be overcome by mixing with a large proportion of drier material. Maize and sunflowers are largely used in America. Although maize may be used for ensilage in the south of England, it is questionable if it is superior in the average season to a good autumn-sown mixture.

The Silo.—The earliest silos were square, wooden, or brick buildings no more than 25 feet in depth, and although they produced good silage in the middle there was always an excessive wastage at the corners where the material was difficult to pack. Experience has shown that a modern silo

should satisfy the following conditions: (1) It should be cylindrical in order that it may be constructed to a given capacity with the least possible amount of material; the absence of corners allows the cut herbage to be compacted with little labour, and the surface at which decay takes place is reduced to a minimum. (2) The walls must be rigid, air-tight, and smooth inside. Strength and rigidity are required because internal pressure is developed during the process of settling; smooth walls are necessary to reduce wastage and facilitate compaction, and it is only by an absence of cracks and crevices through which air may reach the silage that decay can be prevented. (3) The depth should be as much as is practicable, as the greater the depth the greater the pressure on a large part of the silage, and the smaller the loss due to fermentation.

Silos satisfying the above requirements may be constructed of wood, concrete, steel, brick, or stone, the choice of material depending on local conditions. A roof is added to keep out rain and snow; a window should be provided so that the use of a lantern is unnecessary when the silage is being removed, and there should be a door to admit the pipe from the cutter. A row of doors is constructed from the top to the bottom, so that workers can get access to the silage no matter what the level of the material may be; it is through these doors that the forage is thrown when it is wanted for stock. A chute is built over the doors to prevent the silage from being scattered when thrown out, and to enable it to be collected in a barrow, or the chute may be constructed so that it delivers the material into the mixing shed. A permanent ladder is fixed beside the doors or inside the chute.

The size of the silo is important, and the dimensions must be suited to the requirements of the farm. The diameter is determined by the amount of silage to be fed daily, as, in order to prevent decay, as much as 2 in. of silage may have to be removed from the entire surface each day once the feeding of it is commenced, and a broad silo is therefore quite unsuitable where a small number of

animals is kept. If an estimate of the daily requirement of silage is made, the following table can be used as a guide in fixing the diameter of the silo :—

Inside diameter of silo.	Weight of silage in 2 in. layer[1] = amount to be removed daily.
10 feet	650 lb.
11 „	787 „
12 „	937 „
13 „	1100 „
14 „	1275 „
15 „	1475 „
16 „	1675 „
17 „	1887 „
18 „	2125 „

The depth should be sufficient to enable the silo to hold enough material for the full season's requirements; a silo which is deep in proportion to its diameter is advantageous in that its contents become more compact; this not only reduces fermentation and loss but enables a greater weight of silage to be held per cubic yard. Assuming that the diameter has been fixed and the season's needs estimated, the following table,[2] page 292, will indicate the height of silo required; it should be noted that the figures are for settled silage, it having been shown that the material will sink 4 and 8 ft. after the preliminary filling of 24 and 44 ft. silos respectively.

A combined chaffer and blower is employed for filling the silo, the objects of cutting being to ensure more uniform pressure, to facilitate packing, and to reduce waste when feeding the silage later on. The machine is built on the same lines as a chaff cutter, but is provided with a powerful fan which causes a draught of air to carry the cut herbage

[1] These figures are prepared on the assumption that 1 cubic ft. of silage weighs 50 lb. The volume weight, however, is influenced by the pressure of the superimposed layers. When the silage is 30 ft. deep, the average weights per cubic ft. in (*a*) the top $\frac{1}{3}$ and (*b*) the bottom $\frac{1}{3}$ are 40 and 60 lb. respectively.

[2] Prepared from data in King's *Physics of Agriculture*.

through a length of piping to the top of the silo, and then into a distributing tube (which is made in sections so that it can be adjusted to any level) by means of which it is uniformly spread. The chopper is usually driven by a tractor, and is capable of cutting the herbage into lengths varying from $\frac{1}{4}$ to $1\frac{1}{2}$ in.

Capacity of Cylindrical Silos in tons.

Depth of Silage (after settling).	Inside Diameter in feet.				
	10.	12.	14.	16.	18.
24 feet . .	37	...	...	...	...
26 „ . .	42	61	...	...	...
28 „ . .	47	67	92	...	...
30 „ . .	52	75	101	...	...
32 „ . .	...	82	111	146	...
34 „ . .	...	89	121	160	...
36 „ . .	...	97	132	172	219
38 „ .	...	...	142	186	236
40 „ . .	...	...	154	201	255
42 „ . .	...	...	...	215	274
44 „ . .	...	...	...	231	292

Filling the Silo.—The procedure in filling the silo will depend to a considerable extent on the condition of the crop when it is cut. If the herbage is immature and full of sap there will be a danger of the silage turning out rancid if filling is carried out quickly; in such a case it will be advisable to fill for one day only and to allow the temperature of the material to rise before adding more. If each lot is allowed to heat to some extent before fermentation is checked by the addition of another cutting, filling may be possible only on alternate days. On the other hand, dryish herbage should be filled as expeditiously as possible, and it may even be necessary to add water to the last layers so that the pore spaces will be better filled and the temperature kept from rising too high. As it is unlikely that more than 20 tons of material can be filled in a day, the time required to fill a 200-ton silo will be considerable, and the crop will have advanced in maturity from the

commencement to the end of the operations; moreover, the first portions will necessarily be cut fairly green and filled at intervals, and although the remainder of the filling may be continuous owing to the drier nature of the herbage, the whole operation is unlikely to be completed in less than two weeks. Thus, in this case, cutting must commence about a week before the crop is considered to have reached an ideal condition, and some fermentation may have to be encouraged to begin with, while the last portion will be cut seven days too late and everything should be done to prevent fermentation going too far. Another way of controlling fermentation is to cut soft green crops and allow them to wilt for some time in the swath before filling, while crops with a smaller moisture content may be carted as soon as they are mown.

The crop is cut with a mower or a binder. The time of cutting depends on the district; it is usually about the beginning of July in the midlands, and as late as the end of August (spring-sown crops) in the north of Scotland. Almost any vehicle can be used for carting, but owing to the heavy nature of a green crop the use of small-wheeled bogies, such as are used in some districts for carting hay, will reduce labour and expedite operations.

The material is passed into the silo through the chopper as already explained; as filling proceeds the distributing spout is shortened by the removal of first one and then another of its sections, and the doors are clamped into their places. Throughout the filling operations it pays to have one or two men in the silo for tramping the material well down, particularly near the walls where it does not readily consolidate. Particular care has to be taken in finishing off the filling, as the uppermost layers are under practically no pressure and are very apt to ferment and decay. The last of the forage crop should be filled in a thoroughly wet condition so that it may settle into a fairly solid mass, and if the herbage is on the dry side 40 or 50 gallons of water should be slowly poured over it as it is entering the cutter. After this it is wise to add a protective

layer of useless green stuff obtained by cutting the docks, thistles, nettles, etc., in the stackyard. The top is then well trampled not only when filling has been completed but every day until the material has stopped settling. Rotting will take place at the surface, but when the work has been carefully finished the damage will go no further than the uppermost layer of rubbish.

When emptying the silo the rotten material on the top has to be put on a dung heap away from stock; it must not be fed as decayed silage may cause fatalities. The necessary two or more inches are then removed from the surface each day, and the silage is thrown down the chute and fed alone or in mixture with concentrates.

Pit or Trench Silage.—The earliest practice of ensilage was associated with the use of pits, and for a long time refuse such as sugar-beet pulp has been preserved on the Continent by carting it to excavations and covering it with a good layer of soil. In parts of America where wooden silos do not suit the climate, and where the cost of bringing cement, gravel, etc., long distances is prohibitive, circular pits are made and lined with 1 to 1½ in. of concrete: they are constructed to hold 100 to 200 tons, and require but a fraction of the material needed for an overhead structure; but a hoist is necessary for the removal of the silage.

In this country trenches are sometimes constructed for ensilage. The trench is made about 4 ft. deep, 5 yards wide, and as long as is necessary, and in order that the herbage may become thoroughly compacted on settling, the sides are made to slope. Free-draining land should be selected so that water will not soak into the pit and damage the silage; if this is impossible some kind of drain should be improvised. The crop is carted and tipped into the trench in the long state, and when ground-level has been reached the carts are drawn right across to assist in its consolidation. More and more herbage is heaped on until horses can no longer pull their loads over, and the mass is then topped up by hand like a stack of hay. Everything must be done to make the consolidation thorough,

and tramping with a horse will be found very helpful. Inferior or spoiled herbage is used for the last layer, and the trench is finally covered over with at least 1 ft. of earth. When the silage is required for use, the earth is removed from one end of the trench and the material cut out with a hay-knife.

The advantage of this method of ensilage is that capital is required neither for a silo nor for a chaffer, and it would appear to be a system which might be adopted in order to save a crop which would otherwise be lost. However, there is little doubt that decay at the surface of the heap results in great losses, and a layer of rotten material a foot or more in thickness has generally to be discarded. Moreover unless the bottom layer has been wilted for a time in the field it is apt to become so compact that it develops into rancid silage.

Stack Silage.—Ensilage may be carried out by building the green herbage into a stack like hay, and topping it off with heavy material which will produce consolidation. A stack of this kind will develop over its whole surface a layer of decay, which, by preventing further access of air, finally checks fermentation. Obviously such a method is even more wasteful than pit ensilage, but it is nevertheless sometimes practised.

Round stacks are to be preferred for this purpose as they have a relatively small surface; they are usually made about 15 ft. in diameter, but this will, of course, depend on the amount of crop that is to be handled. At first the herbage is tipped on the site of the stack in the usual way, but when a height of 3 or 4 ft. has been reached a horse-fork should be employed to raise the forage. Building is continued until a height of 14 or 15 ft. is reached, and the walls are kept as nearly vertical as possible. The sides are then plucked or trimmed and the loose material is heaped up on top, keeping the stack well "hearted" to allow for sinking. Trimmings from hedge-sides or other poor forage is then added and the whole covered over with a foot of earth, which is best elevated by attaching a hopper to the

horse-fork gear. When the forage has settled it is well to top the stack with thatch, as earth will not run off rain. Sometimes a stack of this kind is protected and consolidated by building on top a small stack of hay.

Owing to the great surface exposed to the air, very active fermentation may take place in a silage stack, particularly where the material has been got in a rather dry condition, and the high temperature may lead to excessive browning. If danger of this is apprehended, fermentation may be retarded by sprinkling on a few cwt. of common salt during the building process, or, if the stack is already built, 30 or 40 gallons of brine may be poured into the top. On the other hand, if the crop is immature, rancid silage may form in the centre and bottom of the stack, though this is never likely to happen near the top and sides, and it may be well to pause in the building after the first 6 or 7 ft. have been erected so that the temperature may rise sufficiently high to check the butyric acid fermentation.

The silage is cut out of the stack with a hay-knife when required, but at least the outer foot will be unfit for fodder.

CHAPTER VII

GRASSLAND

Types of Grassland.—There is an enormous variation in the botanical composition and feeding quality of grasslands. At one extreme there are the poorest natural grazings that are fit only for wild game, while on the other hand there are artificially sown and intensively managed pastures and meadows that produce the best class of meat and fodder. Owing to the number and diversity of the factors on which the characteristics of grassland depend, it is difficult to draw up a completely satisfactory classification of the different types, and although the following broad divisions have been adopted it should be understood that every type in itself will represent great variety.

1. *Mountain and Heath Pastures* have so many characteristics in common that they may be grouped together. Their quality depends on exposure, depth of soil, drainage, etc. Very often the soil is so acid that it produces only a limited flora of innutritious plants; in most cases numerous factors contribute to make the land relatively infertile. The dominant species on many of the best hill grazings are fine-leaved fescues and Agrostis. On many acid areas there is little but Nardus, while where the soil is very wet the chief species may be Molinia. Common non-gramineous plants are heather, bilberry, whin, bracken, and sedges. These pastures are usually stocked with sheep but they are also used as grazings for ponies and hardy cattle; in some cases they yield the highest rents when used for deer.

Heath and mountain pastures are as a rule of little value for fattening purposes but they nevertheless provide a sufficiency of nutritious forage for the rearing and grazing of stock during the summer growing season. Hill-bred lambs

are normally sold off as store sheep in August, and on many poor grazings it is even necessary to send away the ewe hoggs to better grassland before the advent of winter. Usually there is enough rough forage remaining in autumn to maintain the breeding ewes throughout winter, and artificial food need only be given when the ground is overlaid with snow. The greatest scarcity of food occurs in spring after a hard winter, when the ground is very bare and there is yet no new growth. Sheathing cotton sedge—a common plant on wet peat—is very valuable in spring because of its earliness.

Most hill and heath pasture is quite incapable of giving an adequate return for manuring and intensive management; indeed the cost of liming alone may be more than the capital value of the land. However, there are useful improvements that can be carried out in slack seasons at little cost. Open drains may be dug to reduce areas of stagnant peat or to spread water from mineral springs. Coarse grass and heather can be burned to promote the development of more succulent foliage. The planting of shelter belts and the construction of fences will respectively provide protection from bitter winds and enable the grazing to be better controlled. Store cattle, by consuming rough herbage that is neglected by sheep, will usually improve the quality of a sheep run.

2. *The Downs.*—The grasslands of the Downs and Wolds possess certain qualities which may be attributed to the calcareous system which they overlie; but in most cases the natural fertility has been influenced to some extent by the grazing of stock that has had access to arable crops.

The grasses on the Downs are mostly fine-leaved fescues and Agrostis but the herbage also contains as much as 10 per cent. of legumes, the whole forming a close and fine sward. The land is dry and is noted for its healthful properties, being excellent for the rearing of young animals. Intensive manuring is not usually practised, but this type of grassland very often responds well to applications of phosphates.

3. *Other Permanent Grassland.*—There are large areas of land in this country which for various reasons, such as distance from markets, excessive rainfall, or heavy labour costs, cannot be made to yield a profit under arable cropping; they are therefore put down to grass and used for stock farming. On the other hand, even in intensively farmed arable districts a few paddocks of permanent grass in the vicinity of the farm buildings are almost essential. On mixed farms the local conditions may render desirable the permanent separation of the pasture and meadow land from the arable fields.

Permanent grass does not enter into any scheme of cropping, and once it is established it has to be maintained in good condition by manuring and surface treatment. Its advantages as compared with rotation grass are that it does not involve the cost and the risk of periodical re-seeding, and that it is cheaper to maintain in repair the fences and watering places of a few permanent grass fields than to keep every field on the farm in fit condition to carry stock. Disadvantages are that permanent grass in all but the most favourable districts is rather less productive than good rotation grass; it is also less healthful as it may harbour animal parasites.[1]

4. *Rotation Grassland.*—Over a great part of the country where all the fields are fenced and watered and where a sufficient rainfall assures the easy establishment of grass seeds, the fertility of mixed farms is best maintained by resting the fields for a few years under grass between the courses of arable cropping. This enables bountiful arable crops to be grown with a minimum of manuring, particularly where clovers and other legumes have built up a good reserve of nitrogen in the soil. The grass in its turn benefits from the tillage given to the arable crops, and the fresh acreage which is sown every year can be relied on as being clean and healthful. As the grass is usually ploughed up after two to five years it has little chance, if well established, of becoming seriously weedy.[1]

[1] For management and improvement, see later sections.

Quality in Herbage Plants. — The value of a herbage plant depends to a great extent on the environment in which it is to be grown. For example a grass that is highly valued on an upland pasture might be considered a useless weed on an alluvial meadow. Again, a plant that gives satisfaction in a shady orchard might be far from ideal on the chalky Downs. However, generally speaking, the following may be looked upon as the principal points that determine the value of any particular species :—

(1) It should produce the greatest possible bulk per acre.

(2) The food value should be high, that is, not only should there be a high proportion of nutrients as found by analysis, but they should be easily digested and available to the stock.

(3) The plant should possess the quality of palatableness, as no matter what its theoretical value may be it will be useless to the farmer if it is not consumed by his animals.

(4) The plant should grow well throughout the season, springing up early in spring and flourishing right on to late autumn. It is found in practice that certain plants produce bulk early and grow very little during the remainder of the year. Others do not shoot rapidly after they are grazed, and if cut, yield little or no aftermath. Obviously it is only by a knowledge of the characteristics of the different varieties that an ideal mixture can be prepared for any particular case.

(5) The plant must be hardy, and should resist cold, drought, flood, and disease.

Agricultural Characteristics of Grasses.

In the following description no attempt is made to compare the grasses botanically, but the account is limited to those points which interest the farmer and are essential if the selection of plants for any particular environment is to be understood, and suitable mixtures are to be sown. Many grasses in this country have an agricultural significance, but the description does not include the so-called weed grasses, nor those natural species which it does not fall to the lot of the farmer to sow.

Top Grasses.

Italian Rye-grass (*Lolium italicum*).—Italian rye-grass originated in Lombardy, and is believed to be a cultivated variety of the common perennial species; it was first brought to this country about 1833. The grass is short-lived, and dies out towards the end of its second season, but where it is grazed and a proportion is allowed to seed it may linger in a pasture for many years. Its habit of growth is to form more or less erect tufts, and its inability to make a good bottom is evinced by a patchy appearance of its stubble. The grass makes great demands upon the soil, and its full capabilities are only realised on land that is deep, rich, and moist. It suits clays that are not liable to flooding, and black-top land, but it has little value on soil that is poor, thin, and light. The great agricultural value of Italian rye-grass depends on its capacity to produce bulk in the first season of its growth, and on this account it is the basis of all one-year mixtures; it has probably no equal for the production of stubble grazing after its nurse crop has been harvested. It grows to an appreciable extent during winter and it is one of the best herbage plants for early spring keep. Its qualities of productiveness and quickness of growth after mowing or grazing are far above the average, and make the variety particularly useful for irrigation and sewage manuring. Indeed where rye-grass can be periodically treated with liquid manure it is capable of producing four or more cuts per season. For short duration grassland it is superior to perennial rye-grass both in yield and feeding quality, but only a small proportion should be used for leys of long duration as it dies out and leaves spaces that are occupied by weeds.

Italian rye-grass has a disadvantage in that when sown in quantity with clovers and slow-growing grasses, and allowed to develop strongly, it has a smothering effect which prevents the other species from becoming well established; but this harmful competition does not occur if the herbage is grazed. In some districts it is unpopular

for growing with red clover for hay, as when these plants are cultivated together the clover contributes little to the total yield.

Italian rye-grass may be sown by itself, but it is more usually sown in mixture with other grasses and clovers. Sometimes it is grown as a catch-crop after early potatoes, and then a heavy seeding of about 50 lb. to the acre is employed. In permanent mixtures 3 or 4 lb. of seed is considered to be sufficient.

The seed is mostly obtained from the north of Ireland and from France. It is usually graded according to its bushel weight, which varies from 16 to 23 lb., and the heavier samples command the higher price.

A variety known as Westernwolths grass was introduced from Holland about sixteen years ago. This sort grows with even greater rapidity than Italian rye-grass but dies out after the first season; it is most usefully employed for catch-cropping.

Full seeding per acre = 39 lb.

Perennial Rye-grass (*Lolium perenne*).—This is a natural grass that grows freely in all parts of the British Isles, and indeed in most temperate countries. The grass thrives on rich loams and clays, and on such land in districts where the climate is good it is truly perennial, but on poor, light land, and under northern conditions, it is liable to die out during its third year; moreover, on dry soils it is little resistant to drought. The persistence, however, depends a great deal on the strain of seed: most of the plants from ordinary commercial seed disappear in a relatively short time, but it is nevertheless possible to obtain the seed of reliable indigenous types. In comparison with Italian rye-grass, the perennial variety is hardly such a good yielder, it does not stand so well when grown for hay on rich soil, and it does not grow so quickly after cutting. When it is used as a constituent of a permanent mixture its chief function is to produce bulk in the second year of the grassland, before the most productive of the permanent herbage plants have attained their full development. Not

more than 5 or 6 lb. per acre should be used for this purpose for fear of the plants dying and leaving the ground unoccupied.

Perennial rye-grass seed is largely grown in Ireland and south-west Scotland, and, like the Italian variety, is graded and sold according to its bushel weight, which varies from 20 to 28 lb. When Ayrshire farmers thresh the crop for seed they generally obtain a yield of from 6 to 8 cwt. per acre.

Full seeding per acre = 39 lb.

Cocksfoot (*Dactylis glomerata*).—Cocksfoot is indigenous to this country. It is now grown in nearly all temperate regions, and is known in America as orchard grass. The plants are somewhat slow to mature, though even at the end of one year their yield compares favourably with that of any other grass, but it is not until the second or third year that they produce their maximum. Cocksfoot's habit is to establish a deep, strong root system, which gives it an extraordinary power of resistance to drought, and a thick-tufted habit. Its yield is greater than that of any other grass, and its feeding value is very high. It is sometimes said that cocksfoot produces coarse, patchy herbage that is little relished by stock, but such a state of affairs can result only from bad management. Obviously, if a plant of our greatest bulk-producing grass is surrounded by inferior species it will look strong and tufty in comparison. The remedy is to seed cocksfoot thickly so that the plants develop evenly over the field, and to keep it well grazed to prevent strong stems and flower-heads from developing. The great value of cocksfoot lies in its power to produce good herbage on thin, dry soil, and on average soils in dry seasons, though, needless to say, it does much better under good, moist conditions. It comes very early in spring, starting growth about the same time as foxtail, and after grazing or cutting, it shoots with extraordinary rapidity. It withers in autumn under the influence of frost and it is very inferior to the rye-grasses for winter keep. It should be cut early if for hay as its shoots soon become wiry and unpalatable.

Before the management of the grass was well understood it was usual to use 2 or 3 lb. of its seed in "seeds" mixtures, and the result was a somewhat patchy herbage. But on suitable land it is now common to make cocksfoot the basis of the pasture, using 8 or 10 lb. of seed; other seeds are only included to increase the bulk in the first two years and to form a compact bottom. Indeed some farmers go as far as to use cocksfoot and wild white clover alone, the former to produce the bulk and the latter to ensure that the ground will be thoroughly covered.

Most of our cocksfoot seed is imported from New Zealand and the Continent; its condition and germination are usually very good; its bushel weight averages about 18 lb.

Full seeding per acre = 20 lb.

Timothy (*Phleum pratense*).—Although timothy or cats-tail grass is an indigenous species, it was first grown as a cultivated variety from seed imported from America. It is found growing on all the soils of this country, but while it produces a wonderful yield on wet and heavy land it does badly on sandy soil, and on soil that is apt to dry out in summer. It is the typical grass of the heavy clays, and in hollows that are difficult or impossible to drain it does better than any other species. It is a slow-growing grass that ripens about a month after rye-grass, and it gives little or no aftermath. Under suitable conditions, however, it yields an enormous bulk of palatable and nutritious fodder. Timothy is frequently grown by itself, timothy meadows being very common on heavy-land and peaty farms, and the produce is usually cut for hay, as this species yields better under a system of mowing than one of grazing. The hay is largely sold to the towns, and is greatly valued as fodder for livery horses and horses doing fast work, most job-masters considering it to be better than either rye-grass or clover. Timothy is also grown to a great extent for hay in America, and at times it is exported to this country. It is nearly always wise to include timothy in mixtures for leys of two or more years' duration on heavy land, and under suitable conditions it may reach its maximum yield

in the second season. Plants grown from imported seed are not likely to be absolutely perennial, though they may last eight or ten years. There seems to be no doubt, however, that truly perennial wild or natural strains can be found—some of them at great elevations—but it is doubtful if their selection and cultivation would be advantageous, as, while longevity and hardiness would be gained, quick maturity and yield would probably be sacrificed.

Timothy seed is very small and usually cheap: it is imported from America and the Continent, and is largely grown in south-west and central Scotland, where yields of from 4 to 5 cwt. per acre are obtained. The seed weighs about 48 lb. to the bushel; on average land it is usual to sow about 2 lb. in mixture with other species.

Full seeding per acre = 12 lb.

Meadow Fescue (*Festuca pratensis*).—Meadow fescue is one of our natural grasses, and is a common constituent of the herbage of good old pastures, thriving best on moist clays, but never growing on sands unless they are well watered. It produces a large and nutritious yield, but should be grazed down or mown as soon as it flowers, since it becomes woody and loses its feeding value when it ripens its seed. It is commonly used in putting down pastures for three or more years if the soil is suitable. When once established it is truly perennial. There are places, however, where, in spite of good soil and genial climate, meadow fescue will not grow. It is safe to say that many farmers sow it year after year without a plant ever appearing in their fields, because they depend entirely upon their seedsman and cannot recognise the species they are endeavouring to cultivate. Before sowing this grass, then, the farmer should make himself acquainted with its appearance, see if it grows in his locality, and sow it only when he is satisfied that it will thrive in his pastures.

Meadow fescue seed is imported from America, New Zealand, and the Continent: it germinates exceptionally well and weighs about 30 lb. to the bushel. Unfortunately for the farmer, the seed is not readily distinguishable from

that of perennial rye-grass, and samples purchased for fescue often contain a proportion of the much cheaper seed.

Full seeding per acre = 33 lb.

Tall Fescue (*Festuca elatior*).—This is a variety closely allied to meadow fescue, but it is much hardier, more tufted in habit, and produces a greater bulk of coarser herbage. The grass is rather too coarse to justify its recommendation for good land, but, because of its indifference to habitat, it is exceptionally valuable on soil that is either too wet or too dry. The plant, which takes about four years to reach maturity, develops a very strong and deep root system, and remains almost unaffected by drought. It produces a really good bulk very early in spring but if grazed hard at this time its persistence will suffer. It chief value is for poor thin soil where, perhaps one season in three, the good grasses produce little herbage through want of rain. This variety of fescue is usually sown in mixtures at the rate of 3 to 6 lb. per acre, and the poorer the land the heavier is the seeding given.

The best seed has hitherto been obtained from the Continent, and weighs about 24 lb. to the bushel; it is more elongated and darker in colour than that of meadow fescue.

Full seeding per acre = 35 lb.

Tall Oat-Grass (*Avena elatior*).—This is a common roadside plant, especially on land of a sandy nature. It must not be confused with bulbous oat-grass, which is a troublesome weed. Tall oat-grass grows on almost all soils, provided they are not too wet, but its agricultural importance lies in its hardiness and resistance to drought; it is, therefore, not sown to any great extent except on land that is apt to dry out. It is a great bulk-producer, being perhaps as good as cocksfoot in this respect, and the only reasons why it is not used more generally are that it is a little bitter and may be neglected by stock when more palatable herbage is available, and that the seed is somewhat costly. It is frequently used in mixtures sown for pastures of four or five years' duration, but as it begins to die out about the

fifth year, it is not very suitable for grassland intended to be permanent. One may conclude, then, that it is an ideal grass to grow on light land on long rotation systems, where our best grasses grow indifferently.

The seed of tall oat-grass is largely imported from France, where the species is very generally grown and is known as French rye-grass. Although the price of a given weight may not seem unreasonable, the price per million of germinating seeds is very high because of the large size of the individual seeds. The average weight of the seed is 16 lb. to the bushel; when used in seed mixtures it is usual to employ 4 to 6 lb.

Full seeding per acre = 57 lb.

Meadow Foxtail (*Alopecurus pratensis*).—Meadow foxtail is an indigenous grass common to our rich and heavy soils; it requires plenty of moisture and dies out on land that is subject to drought. On medium land it is sometimes found in damp hollows and shady hedge sides, but not on the drier parts of the fields. Its habit of growth is to produce both top and bottom herbage, and it covers the ground well when sown alone. The plants take about three years to attain their maximum development, but they never produce as much bulk as rye-grass, cocksfoot, etc. It flowers too early for hay and it is not very palatable in pasture. For earliness foxtail surpasses every other cultivated species: it commences growth with the lengthening days and is in flower by April, producing a fair bulk when most other grasses are practically dormant. As the grass is truly perennial and slow in developing, it is not often used in short rotation mixtures, its use being almost exclusively for permanent pastures. It is usually seeded at about 4 lb. per acre in mixtures, though up to 10 lb. may be used on suitable soil.

The seed is imported from the northern European countries: it weighs about 14 lb. to the bushel.

Full seeding per acre = 24 lb.

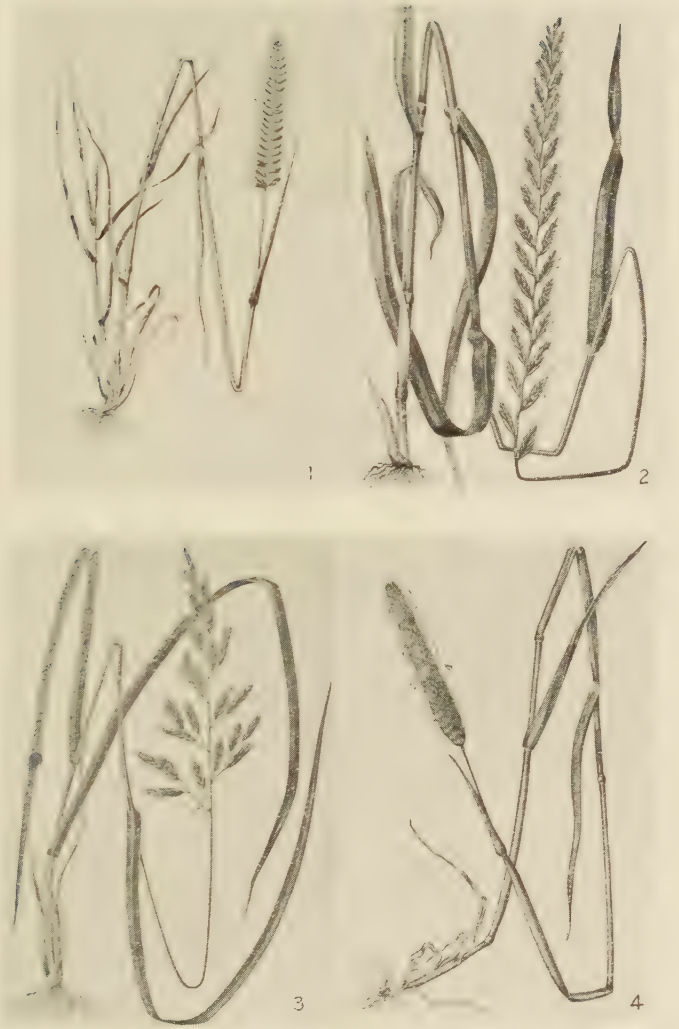
Bottom Grasses.

Rough-stalked Meadow Grass (*Poa trivialis*).—This is one of our common "natural" grasses, and is particularly abundant in our wetter districts and on our heavier soils. It is a true perennial, growing well from seed and maturing in its second year; it produces a large amount of foliage, starts growth early, and is extremely palatable. Rough-stalked meadow may be looked upon as the finest bottom grass for good land, though, in fact, it is intermediate between typical top and bottom grasses in habit of growth. Because of its stoloniferous habit it spreads rapidly over the ground, soon forming a compact turf. It is, however, shallow rooted, and while it does well on damp soil and grows to perfection under irrigation, it produces little or no foliage during periods of drought and should not be used on thin, light land.

The seed of *Poa trivialis* is mostly imported from Denmark and weighs about 28 lb. to the bushel. As the seed is exceedingly small, no more than 1 lb. per acre need be sown in any mixture.

Full seeding per acre = 8 lb.

Smooth-stalked Meadow Grass (*Poa pratensis*).—Smooth-stalked meadow grass is an indigenous species, and has been introduced into America, where it is known as Kentucky blue-grass. Although very closely related to the rough-stalked variety it is in every way inferior when grown on good soil, taking longer to become established, producing less bulk, and being less nutritious. It is a better grass, however, for poor, open-textured soils, because it develops underground rhizomes which increase its resistance to drought; it does very well on calcareous soils. It attains its maximum development about the fourth year, and by that time forms a close mat that conserves moisture and prevents the development of weeds. It may be sown as a bottom grass on second-class soils and land liable to drought. Because of its creeping habit it is difficult to eradicate and unsuitable for alternate husbandry.



[Sutton

FIG. 44.—(1) Crested Dogstail. (2) Italian Rye-grass (3) Meadow Fescue. (4) Meadow Foxtail

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FIG. 45.—(5) Perennial Rye-grass. (6) Cocksfoot
(7) Rough-stalked Meadow Grass. (8) Smooth-stalked Meadow Grass

[*Sutton*

FIG. 46.—(9) Timothy. (10) Sweet Vernal. (11) Fiorin (12) Yellow Oat Grass

The seed is small, weighs about 32 lb. to the bushel, and is mostly obtained from North America.

Full seeding per acre = 10 lb.

Crested Dogstail (*Cynosurus cristatus*).—This grass is common all over our country, being found at all elevations and on all kinds of soil, and is therefore both hardy and drought resisting. The plant grows very slowly and very close to the ground, and does not reach its maximum until about the third season; it is essentially a bottom grass which will permit the closest grazing but is useless for mowing. Although the wiry flowering shoots are never eaten by stock, the leaves are consumed with relish and the plants provide a considerable amount of green keep for winter. Crested dogstail is unsuitable for sowing on good land, because it undoubtedly spreads by seeding and tends to occupy too great a proportion of the ground, but a little may be sown on poor, cold land for leys of four or more years' duration.

The seed is mostly imported from Holland; it is small, and weighs about 38 lb. to the bushel. Not more than 1 lb. per acre should be sown in a mixture.

Full seeding per acre = 19 lb.

Golden Oat-Grass (*Avena flavescens*).—Golden oat is a common grass in our pastures and roadsides. It grows well from seed and reaches maturity about its third season; it is lasting, extremely hardy and drought resisting. It thrives best on dry or moderately dry soils and is probably the best bottom grass for such conditions; but it is never a good bulk producer, though extremely nutritious and palatable. Golden oat-grass may well be compared with crested dogstail, as their virtues are similar, but where the latter is the bottom grass for poor, wet land, the former is the bottom grass for poor, dry land.

The seed is small, and weighs about 14 lb. to the bushel.

Full seeding per acre = 16 lb.

The Fine-leaved Fescues.—These grasses, which include sheep's fescue (*Festuca ovina*), hard fescue (*Festuca duriuscula*), red fescue (*Festuca rubra*), and fine-leaved fescue

(*Festuca ovina tenuifolia*), form much of the hardiest of our hill herbage; they are all perennial, and although they do not produce much bulk they are invaluable for sheep on poor land. They should on no account be sown on fertile land except in the laying down of lawns, golf greens, etc., and they spread naturally by seeding in their own habitats.

Full seeding per acre = 20 lb. and upwards according to variety.

Fiorin and Sweet Vernal Grasses (Fig. 46) are common perennial species; they are poor producers and of low feeding value; they should never be sown.

Agricultural Characteristics of Leguminous "Seeds."

Red Clover (*Trifolium pratense*).—Wild red clover is found growing in some of our old pastures and hedge sides; it is a rather woody perennial, and although its seed is now on the market it is distinctly less valuable than wild white clover. The cultivated varieties, which have been improved in respect of bulk and early maturity, do not last for more than three years, and many of them die off after the first harvest season; they are divided for commercial purposes into: (1) broad red clover; (2) English single-cut cow-grass, perennial red clover, late-flowering red clover (*Trifolium pratense perenne*), these names being synonymous. In reality cultivated clovers vary greatly between two extremes, one of which is represented by the broad red sort and the other by the late flowering variety.

Single-cut cow-grass differs from the broad red variety in having narrower and more pointed leaves, being more prostrate in habit of growth, ripening about a fortnight later, producing very little aftermath, and lasting for over two years, whereas the broad-leaved sorts die out before the second harvest year. It seems probable that the characteristics of the late-flowering sorts have been developed by a long period of growth in places that are elevated, cold, and late; and since commercial strains are all somewhat mixed in type it is possible that by sowing the seed in a

warm and early district for a number of seasons, the plants would develop the broad red type and habit. This brings us to the questions of source and pedigree. It has been found that clovers grown from seed harvested in this and other cold countries are hardier, more lasting, and produce much more abundant crops than when the seed is grown in warm and early parts, such as Chile or Hungary, though for catch-cropping purposes Chilean seed, for example, is superior, as the plants establish themselves more quickly and produce a fair bulk in a short time. As regards the seed pedigree it is obvious that seed produced in England from a crop grown from Chilean seed will not have the merits of home-grown seed from plants acclimatised for many generations. But unfortunately it is not always possible to pick and choose the original source of varieties.

Red clover grows best on well-drained clay loams which are rich in lime and contain plenty of humus. It usually fails on poor or water-logged land, and the late-flowering variety is best suited to land of the lighter types. The root system is deep and the plants suffer less from drought than do grasses, and the fine fibrous nature of the rootlets gives the crop a great value in improving the texture and friability of heavy clays. Its agricultural value lies in its nitrogenous nature, in its power to produce a great bulk of nutritious foliage which may be grazed, soiled or made into hay, and in its usefulness for green manuring.

Unfortunately, of all our leguminous crops red clover is probably the most uncertain cropper. Doubtless, to some extent, this is due to unsuitable seed, but the plants are very susceptible to soil and climatic conditions, are easily affected by disease and cannot be grown in a close rotation, and are absolutely dependent upon the presence of ample lime, potash, and phosphates in the soil.

Red clover is largely grown for seed in the south-eastern countries. When the broad red variety is grown for this purpose it is usual to secure the first cut for hay and to obtain the seed from the second crop of flowers. The average yield of seed is rather more than 2 cwt. per acre.

Red clover may be sown alone, but it is more usual to sow it in mixture with grass seeds at the rate of 2 to 10 lb. per acre.

Full seeding per acre = 20 lb.

Alsike Clover (*Trifolium hybridum*).—This clover was introduced from the Continent in 1834, and takes its name from a parish in Sweden. Alsike is not a true perennial, but is more lasting than red clover, and on good soil may continue to grow for three or four years. In habit of growth it resembles late-flowering red clover, but the flowers are intermediate in appearance between those of red and white clover, and this has probably led to the erroneous belief that it is a cross between these sorts. It commences growth later and does not produce so much aftermath as broad red clover. Alsike does best on heavy, damp soils, and as it will grow under wet and acid conditions that inhibit the development of the red variety, it is frequently included in mixtures to insure the presence of a plant should the red clover fail; indeed it should always be included where the growth of red clover is uncertain, as its "take" is almost invariably good. It is inferior to red clover, however, in producing bulk, and should the red sort develop strongly the alsike is choked down and its yield is small.

The seed of alsike, which is largely imported from Canada, is small, and when sown with other clovers and grasses, 1 or 1½ lb. per acre should suffice.

Full seeding per acre = 12 lb.

White Clover (*Trifolium repens*).—Dutch white clover is not a true perennial, though it is more lasting than alsike. It is a variety which has a less procumbent habit of growth; it is well suited to form the bottom herbage in temporary leas that are intended mainly for pasture. As it produces very little top foliage it is almost useless for mowing, but it is highly nutritive and excellent for stock. It grows on all types of soil and, being deep rooted, is resistant to drought. It should be included to the extent of about 1 lb. per acre in all mixtures for temporary leas.

Wild white clover is somewhat difficult to distinguish from

the Dutch variety in appearance, but it is smaller, later in flowering, more actively creeping, and absolutely perennial. As it is practically the only perennial legume found in many of our pastures, it has a great significance from the point of view of nitrogen assimilation and the improvement of the soil. It is an indigenous variety, and tends to increase when conditions are favourable; it is particularly drought resisting. Wild white is much more resistant to soil acidity than red clover. Its most luxuriant growth is generally produced by an application of phosphatic manure, particularly basic slag (see Manuring of Grass Land). When very luxuriant it must be carefully grazed, as it is rich and tends to scour stock. Owing to the high cost of wild white clover seed it is unusual to employ more than 1 lb. per acre.

Full seeding per acre = 10 lb.

Trefoil (*Medicago lupulina*).—This is an annual legume which has no value for permanent pastures, but is useful on poor, light, and sandy soil where the better clovers will not grow. It can be used in one-year mixtures only, as in other cases it dies out and allows weeds to develop.

Full seeding per acre = 25 lb.

Kidney Vetch (*Anthyllis vulneraria*).—This is a legume which thrives on poor, light, sandy, and chalky soils; it is extremely hardy and resists both cold and drought. It is not truly permanent but may last several seasons, and can be included in mixtures to the extent of 2 or 3 lb. per acre where red clover will not grow.

Full seeding per acre = 30 lb.

The Purchase of Seeds and the Preparation of Mixtures.

Vendors of agricultural seeds are required to declare the purity and germination of the seeds they offer for sale, and they can usually give the buyers further information with regard to the bushel weights of their samples.

The percentage of pure seed in a sample is made known but the nature of the impurities is frequently of greater importance. At one time seeds were wilfully adulterated

with cheap seed of other varieties, but this is no longer attempted, and impurities consist of grit, chaff, and weed seeds which have been incompletely removed by the dressing and cleaning machinery. Weed seeds may do a great deal of harm if sown on the farm, and farmers should reject samples which reveal their presence.

Although it is sometimes possible to judge the quality of seed by its appearance, colour, odour, etc., its real value cannot be ascertained without recourse to a germination test. This is carried out by counting the seeds into lots of one hundred and placing them in a suitable environment for germination. The number of seeds in each lot which fail to germinate after a reasonable period—usually three weeks—deducted from a hundred, represents the germinating capacity of the sample. When an official test is made the temperature and moisture supply are very carefully controlled, and the speed with which germination takes place is noted. This rate of germination is indicative of the vitality of the seed, and seeds which germinate very slowly in the laboratory may be quite unable to produce healthy plants in the field.

The degree of purity of the seed is obtained by working out the percentage of other seeds, chaff, etc., present in the sample. The "real value" of the seed must take into account both germination and purity: it is got by multiplying the percentage germination by the percentage purity and dividing by 100, and it is on the real value basis that all seeds should be bought and mixtures compounded.

The bushel weight of grain or seed is indicative of the plumpness of the grain, *i.e.*, the size of the food stores on which the plants will have to subsist until they have developed their root and leaf systems. Consequently the higher the bushel weight of a variety the better, and the greater the likelihood of the young plants establishing themselves.

The pedigree of seed merits careful consideration. No farmer would think of sowing a field with oats unless he knew the nature of the variety and the source of the seed.

Although the pedigree of grass and clover seed is of equal importance, it is only recently that any attention has been given to it, and thousands of acres have been sown with strains which were quite incapable of making the most of their environment. Improved strains of forage plants are now being brought out, and the best sources of seed are being investigated, and it is to be hoped that before long farmers will be able to choose the best weather-resisting and bulk-producing strains for their own surroundings.

Seed Mixtures.

It is more usual to sow mixtures of grasses and clovers than to cultivate single species. The reasons for this are, (1) plants of different sizes and habits of growth make more of soil fertility and sunlight when grown in association, (2) the ground is more completely covered and weeds are less likely to gain root-hold, (3) early-growing species can be associated with varieties which produce bulk late in the season, and short-lived varieties, which produce much bulk in the early years of the grassland, can be mixed with more permanent sorts which are slow to mature, and (4) taking one year with another on soils varying in quality and elevation, a mixed herbage will produce a more certain crop than any single variety. Moreover, it is usual to include a proportion of leguminous plants which not only increase the feeding value of the hay or pasture, but greatly improve the fertility of the soil by accumulating nitrogen.

The composition of a mixture depends to a great extent on the number of years the land is to be under grass. It is under arable conditions that the greatest amount of human food is produced per acre, and when corn prices make arable farming profitable it is only under certain conditions, such as remoteness from markets, stiff soil or excessive rainfall, that land is kept permanently under grass. When conditions and prices are suitable, land is most productive under the plough. One-year seed mixtures produce more bulk than two-year mixtures, which in turn are more productive than, say, permanent pasture. The shorter the lea the heavier is

the crop, *i.e.*, the nearer to arable conditions the greater is the productiveness.[1] The reason why old grassland, except under particularly suitable local conditions, is less productive than short leas is that the seeds sown in the original mixture do not determine the ultimate nature of the herbage, since the cultivated species are replaced by indigenous varieties and weeds. The quality of the best old grassland of this country is due to productive indigenous varieties growing under soil and climatic conditions which are favourable to their best development.

In the colder and bleaker parts of Britain, grassland deteriorates fairly rapidly, and a time comes when it is no longer sufficiently productive to be profitable. Under better conditions, however, the herbage often deteriorates to a point following which a condition of comparative stability is maintained, and the grass accordingly continues to yield a profit. This is one of the reasons why one commonly finds in the north a system of long rotations including three or four years lea, while short rotations, associated with true permanent pasture, are more usual in the south.

The most critical time in the life of a pasture is when many of the sown varieties begin to die out and leave bare patches. If the pasture be well managed, good, indigenous varieties should come in about this time, but if manuring is neglected or local conditions are unsuitable, weeds are likely to overrun the land.

In practice, the only seed mixtures which require consideration are those designed for one year, two years, three years, and over three years, and they can only be prepared from a knowledge of the agricultural characteristics of the various species, as outlined earlier in the chapter. In preparing a mixture, the varieties should be selected to suit the soil, climate, and elevation, and according to experience of their actual productiveness on the grassland of the district. Another point of importance is the influence of one species

[1] The writer does not imply that short leas are necessarily most profitable. Because of the cost of seeding, etc., a 30-cwt. crop of meadow hay may be more profitable than a 40-cwt. crop of seeds hay.

on another when grown in close competition. Much costly seed is sown each year which, on account of the unsuitability of the local conditions, produces either no plants at all or very inferior herbage. Seed mixtures may be modified according to whether the grass is to be mown or grazed, or both.

An endeavour should be made to prepare a mixture which will satisfy the requirements enumerated at the beginning of this section, and the relative proportions of the varieties should be chosen with great care. (See following notes on prescribed mixtures.) The number of seeds per acre necessary to produce a close herbage depends to some extent on chance. Should weather conditions be such that a very fine tilth can be prepared, and seeding be followed by ample rains which facilitate rapid and thorough germination, a minimum of seed may be employed. On the other hand, if the soil is heavy and difficult to work, and rains fail, many of the seeds never establish plants, and a heavy seeding is necessary. Unfortunately as these conditions cannot all be foretold, it is necessary to base the rate of seeding on the conditions of an average year. Experience has shown, however, that the number of germinating seeds necessary to sow an acre varies from 6 to 15 million according to the vigour of the species and the area occupied by individual plants. Thus while 6 million germinating seeds of a strong-growing grass like tall fescue will serve to sow an acre, 10 or 12 million would be required for an intermediate-sized variety, and 15 million in the case of a small plant like rough-stalked meadow grass.

At the end of the description of each grass and clover in this chapter, a figure is given which represents the number of pounds of average commercial seed required to sow an acre. These figures are based on the average germination and purity of the seed offered to farmers, and take into account the size of the plants and therefore the number of million seeds required. Their use is intended to simplify the preparation of seed mixtures. However, these figures can only be used for temporary leas, *i.e.*, where the duration

of the grassland is sufficiently short to obviate all possibility of some of the species dying out. For long leas and permanent pasture, an addition of from 25 to 50 per cent., according to the proportion of short-lived species adopted in the mixture, should be made to the prescribed figures in order that the spaces left by short-lived varieties may be rapidly filled up. The method of making this addition is shown later.

Mixtures for One Year.—Rye-grasses and red clover are the quickest-growing and best plants for one year's grass; but red clover may be patchy on certain classes of soil, and it is common to add enough alsike to act as an assurance against failure. If the land is for grazing, Italian rye-grass should be chosen, as it provides good stubble grazing, early spring keep, and quite average summer growth; it also gives very good aftermath if it is found desirable to take one crop of hay. On the other hand, if the perennial variety of rye-grass is selected it does not compete so strongly with red clover, and it is the better sort where the mixture is intended to produce a maximum yield of good mixed hay.

Suppose the district to be an average one, and that the farmer wants herbage that is half grass and half clover, *i.e.*, 50 per cent. rye-grass and, say, 40 per cent. red clover and 10 per cent. alsike. Under both rye-grasses the figure 39 is given as representing the number of pounds required to sow an acre, and the corresponding figures for red clover and alsike are 20 and 12 respectively. Thus:—

50 per cent. of 39 lb.	=	say 20 lb.	Italian or Perennial Rye-grass.
40 „ „ 20 „	=	8 „	Red Clover.
10 „ „ 12 „	= say	1 „	Alsike.
Total seeding per acre	=	29 lb.	

On land which grows good clover the proportion of red clover may be usefully increased; on soil that tends to be "clover sick" less red and more alsike should be employed.

If a closer and more complex mixture be required for

grazing as well as mowing, the following might be worked out:—

40 per cent.	Italian Rye-grass . .	at 39 lb. per acre	=	say 20	lb.
20 „	Late-flowering Red Clover	„ 20 „ „	=	4	„
20 „	Broad Red Clover . .	„ 20 „ „	=	4	„
10 „	Alsike	„ 12 „ „	=	say 1	„
10 „	Trefoil	„ 25 „ „	=	2½	„
		Total seed per acre .	=	31½	lb.

Two Years' Mixture.—For a two years' lea perennial rye-grass should be introduced together with cocksfoot or timothy, according to the nature of the soil, to provide the chief grass constituents during the second season. It is not worth while adding a bottom grass for such a short duration, but white clover should not be omitted. A proportion of Italian rye-grass is necessary to provide bulk in the first season. A mixture on these lines, suitable for average soil conditions, may be prepared as follows:—

30 per cent.	Perennial Rye-grass . .	at 39 lb. per acre	=	say 12	lb.
20 „	Italian Rye-grass . .	„ 39 „ „	=	8	„
30 „	Cocksfoot	„ 20 „ „	=	6	„
10 „	Broad Red Clover . .	„ 20 „ „	=	2	„
10 „	Late-flowering Red Clover	„ 20 „ „	=	2	„
10 „	Alsike	„ 12 „ „	=	1	„
10 „	Dutch White Clover . .	„ 10 „ „	=	1	„
120 = 20 per cent. extra.		Total seed per acre .	=	32	lb.

Note.—Twenty per cent. of extra seed is added to this mixture because some of the red clover and most of the Italian rye-grass will have died out before the end of the second season.

Three Years' Mixture.—If a lea is to be down for three years it becomes worth while to introduce a bottom grass and a small proportion of wild white clover. Suppose the soil to be a light one, at an elevation of from 700 to 800 feet. A proportion of Italian and perennial rye-grasses will be necessary to produce bulk in the first and

second years respectively, and cocksfoot is likely to be the best grass for the third season. On light land, at this high elevation, golden oat-grass will probably be the best bottom grass. The following mixture would be likely to be suitable :—

20	per cent.	Perennial Rye-grass . .	at 39 lb.	per acre	=	say 8	lb.
15	„	Italian Rye-grass . .	„ 39 „	„	=	6	„
50	„	Cocksfoot	„ 20 „	„	=	10	„
5	„	Crested Dogstail . .	„ 19 „	„	=	say 1	„
3	„	Golden Oat-grass . .	„ 16 „	„	=	½	„
10	„	Late-flowering Red Clover	„ 20 „	„	=	2	„
10	„	Alsike	„ 12 „	„	=	say 1	„
10	„	White Clover . . .	„ 10 „	„	=	1	„
5	„	Wild White Clover . .	„ 10 „	„	=	½	„
128 = 28 per cent. extra.			Total seed per acre .			= 30 lb.	

Note.—In this mixture 28 per cent. of extra seed is added to make good the losses due to the dying out of the short-lived species.

If the mixture had to be modified for heavy land at a similar elevation, it would be desirable to reduce the proportion of cocksfoot and to introduce 30 to 40 per cent. of timothy ; rough-stalked meadow-grass would be used in place of crested dogstail, and a higher proportion of alsike than red clover.

Permanent Pasture Mixture.—In a permanent grass mixture it becomes necessary to reduce the proportions of short-lived grasses and clovers to a minimum, consistent with the production of sufficient herbage in the first and second years to make the grassland profitable. No endeavour should be made to grow a large amount of rye-grass in the first seasons for hay, as it tends to choke out the permanent slow-growing grasses and the final condition of the pasture is greatly deteriorated. It is absolutely necessary to sow wild white clover, as it is the only cultivated legume that is a true perennial.

The following mixtures are suggested for three distinct types of soil. The proportions of the varieties in the mixtures should be studied, as they indicate the environments in which the different species find their greatest

usefulness. The columns giving the pounds of seed per acre are prepared in the same way as the earlier examples.

Species.	Good Loam.		Heavy Wet Soil.		Light Dry Soil.	
	Percentage of Area.	Lb. of Seed.	Percentage of Area.	Lb. of Seed.	Percentage of Area.	Lb. of Seed.
Italian Rye-grass	10	4	10	4	10	4
Perennial Rye-grass	15	6	15	6	15	6
Cocksfoot	30	6	...	...	40	8
Timothy	15	2	40	5	...	...
Meadow Fescue	10	3½	15	5	6	2
Tall Fescue	...	...	10	3½	10	3½
Hard Fescue	...	...	...	...	5	1
Meadow Foxtail	12	3	12	3	...	...
Tall Oat-grass	...	...	...	...	5	3
Crested Dogstail	...	...	...	...	5	1
Rough-stalked Meadow-grass	10	1	10	1	...	...
Smooth-stalked Meadow-grass	...	...	...	...	10	1
Red Clover (late flowering)	15	3	10	2	10	2
Alsike	10	1	15	1½	10	1
White Clover	5	½	5	½	5	½
Wild White Clover	5	½	5	½	5	½
Kidney Vetch	...	...	...	...	10	3
Totals	137	30½	147	32	146	36½

It should be understood that the mixtures prescribed above are likely to be satisfactory for average soil and climatic conditions, but the best mixture for any particular field can only be prepared from an exact knowledge of the locality. Heavier seedings may be necessary on northern and high-lying farms, and where the soil is difficult to work; on the other hand, economy in seeding may be effected in parts that are more favourably situated. The present tendency is to reduce the number of species to those that can really make an appreciable contribution to the grassland herbage.

Sowing Seed Mixtures.

Seed mixtures may be sown in spring or late summer either with or without a nurse crop.

The most common method is to sow the seeds along with a corn crop in April or May, so that the plants establish themselves during the time that the cereal is growing into a rent-paying crop ; but the seeds may be put in by themselves, the only argument against the practice being that little bulk is produced during the first season's growth and practically no return is obtained from the land. In all cases where small seeds are to be sown it is of the utmost importance that the seed-bed should be worked very fine, and that the land should be managed so that it contains plenty of moisture and is well consolidated in order to facilitate capillary movement. The fineness of tilth is obtained by judicious use of the cultivator, harrow, and roller ; but the treatment should begin much earlier in the season—when the initial ploughing is performed. In the ordinary process of ploughing an air-space is left below each furrow-slice, and until time and weather have broken down the furrows the upper layers of soil are cut off from their supply of subsoil water. If the ploughing is done early all will be well when seed-time arrives, but a late ploughing may have a disastrous effect upon the seeds in a dry year. Sometimes, however, ploughing cannot be performed until spring, and when such is the case the land should be little more than skimmed and then well consolidated by heavy rollings. It is also important to ensure that the seed is covered but not buried too deeply ; the nearer it is to the surface the better, provided that moisture can reach it. When sowing down grass for a number of years it is well worth while to clean the land thoroughly beforehand so that the young herbage plants will not have to suffer the competition of weeds. As young grass is killed off under lodged corn, a strong strawed variety of cereal should be chosen as a nurse crop ; moreover, the grain crop should be given a light seeding so that it does not have a smothering effect. If mineral manures or lime

are necessary for the grassland, they will produce their most beneficial effect when applied at or before seed-time.

There is a great difference of opinion as to whether the seed should be sown before the grain crop is through the ground or later in the season when the plants are a few inches high, and as to the tillage operations immediately before and after sowing. It will be found, however, that the system adopted on any farm is largely determined by conditions of soil and weather. The following hints may be useful in determining the procedure in any particular case :—

1. Because of the impossibility of preparing a fine tilth when the cereal is sown early on wet clay soils, the seeds should be put in fairly late. The operations should be to harrow, to sow, to light harrow, and to roll when the soil is so dry that there is no risk of a crust forming.

2. On light land sowing should not take place unless there is sufficient moisture to bring about germination. If the land has been ploughed early the operations should be to harrow, to sow, to light harrow, and to roll heavily; but if ploughing has taken place late, the soil should be consolidated by heavy rolling before the seeds are put in.

3. On black-top and very rich soils the seed should be put in immediately after the cereal, because the grain crop is likely to have rank and luxuriant foliage, and unless the seeds can become established before the corn gets up they are apt to be choked out altogether.

4. On average or poor soils sowing should be delayed as much as possible, provided that risk of drought is not incurred, because early-sown clovers may grow almost as fast as the corn, with the result that the sheaves are very difficult to dry at harvest-time and the legumes may be so weakened that many of them die off in winter.

5. If the mixture is to be sown in spring on land that is carrying a winter cereal, there may be some difficulty in getting the seeds properly covered. When the surface is caked and hard owing to the beating action of winter rains, a very heavy preliminary harrowing is necessary. If the

corn crop be strongly developed and wet weather prevents surface treatment, it is better to broadcast the seed during the wet spell and let it take its chance than further to delay sowing in the hope of being able to prepare a seed-bed.

The seed is usually sown by means of a broadcasting seed-barrow, but it may also be broadcast by hand; in warmer and drier districts drilling is common. It is a good plan to use a Cambridge roller for the consolidation of the soil immediately before sowing, as it gives the surface a corduroy-like pattern with regular depressions into which the seed falls, and where it can be covered to a regular depth by light harrowing. On no account should the seed be sown when the weather is hot and dry, as it will not germinate, nor should it be sown when a strong wind is blowing, because this makes even distribution impossible. Some farmers divide the seed into a light portion containing grass seeds and a heavy portion containing the heavy grass and clover seeds, and after sowing the first portion, sow the other at right angles to it; this ensures a more even distribution of clovers and grasses.

Circumstances sometimes arise that make spring sowing of seeds impossible, or seeds may be sown and afterwards killed by drought or flood. It then becomes necessary to perform the seeding in late summer when the stubbles are cleared. This, however, can be done with perfect safety in August, but if it is necessarily postponed till September it is attended by the risk that the plants may be destroyed by early frosts before they have become well established. It is not, as a rule, necessary to plough the land, as a sufficiently good tilth can usually be prepared by cultivating and harrowing.

If the grassland is sown down for a number of years it should be given just sufficient grazing in the first autumn to prevent the herbage from becoming winter proud. In most cases it is better not to stock the land in wet weather for fear of poaching the soil. When the seeds are to be grazed in the following year the plants should be allowed

to develop and become well established in early spring, for if the stock is turned on before May young grass may receive a set-back which reduces its future yield. When hay is taken in the first year the crop should be cut very early in order to prevent the strong grasses from smothering the more delicate species.

On land at high elevations or otherwise unsuitable for the cultivation of a cereal, grass mixtures may be sown together with a cover crop of rape. (See also p. 342.)

Seasonal Variation in Grassland.—The growth of herbage plants varies considerably from year to year according to the rainfall and the temperature of the season. In years when favourable conditions result in bountiful yields it may be impossible to secure sufficient stock at economic prices for the consumption of the forage, and much food material may be wasted. On the other hand dry seasons are usually times of scarcity which have to be met by the purchase of supplementary foods for the maintenance of the grazing animals. In practice the grazier must stock his land according to its carrying capacity in an average season.

The productiveness of grassland also varies enormously from month to month throughout the year, the relative monthly growth depending on the situation and climate, the fertility of the land and its manurial treatment, and the nature of the herbage. During winter, growth is either very slow or entirely checked, and although the plants may develop to some extent during mild periods it is probable that the total growth from the beginning of November to the middle of April does not exceed 10 per cent. of the annual yield. Indeed in cold and elevated districts winter keep may consist very largely of rough grass remaining in the pasture from the previous summer. A better supply of winter and early spring keep can be secured by cultivating in a good sheltered field a winter green species such as Italian rye-grass and manuring it liberally with a nitrogenous fertiliser.

The main growth of herbage takes place from the beginning of May to the end of October, and the following

table gives in round figures the productiveness of grazing land from month to month:—

Month.	Yield as Percentage of Total Summer Growth.
May	31
June	25
July	20
August	12
September	8
October	4

While these figures cannot be applied to all grasslands because of the variations brought about by local conditions, they nevertheless show the general trend of productiveness throughout the grazing season. The table makes it obvious that if a pasture is fully stocked to the end of July, it will be necessary in August either to reduce the number of animals or to provide supplementary foodstuffs. In practice this reduced carrying capacity of the pasture in August is met by the sale of lambs as store sheep and by the feeding of roots or cake to grazing cattle. If the grassland is put up for hay and mown at the usual time, about two-thirds of the season's yield is secured in the hay crop; the growth for the remaining months may be grazed or used in part to produce a second cut of hay.

With regard to the quality of the herbage, the nutritive value of the leafage is considerably higher than that of the leaf sheaths and flowering shoots; moreover young or closely grazed foliage is better and contains a higher proportion of digestible nitrogenous material than that which has become relatively mature. In order to secure the herbage in its best condition it is therefore advisable to keep the pasture closely grazed and to prevent as far as possible the development of flower heads. The feeding quality of grassland is also influenced by the rainfall. The growth that is produced in a normal year has better feeding and fattening properties than either the soft luxuriant herbage of a wet season or the fibrous and relatively indigestible product of a dry summer.

Considering together the seasonal variations in the bulk

and quality of grassland herbage, it is clear why stock can be made prime fat on grass without supplementary food only in the May to July period. Fat may be developed to some extent by animals on pasture during the latter part of summer, but prime condition can rarely be attained on grass alone. During winter animals will not fatten on grassland.

Middleton has shown that the capacity of grassland for the production of meat may reach 300 lb. live weight increase per acre per season on the finest permanent grazings, 200 lb. may be got on an equal area of well-managed average grassland, while 30 lb. may be the maximum obtainable from poor land.

THE MANAGEMENT OF GRASSLAND.

Grassland for Hay.

Seeds-Hay.—The term "seeds" is loosely applied to hay that is obtained from temporary grassland; but in some cases it is meant to refer in particular to the first crop taken after grass has been seeded down, and if the herbage is again cut in the following years the terms second and third year's hay are employed. On the other hand, the produce obtained from old grass is called "meadow"-hay, but it is clear that in the case of land that is seeded down and mown year after year the crops that are first called "seeds" must ultimately be termed "meadow," and there is no hard-and-fast line between them. As a rule, however, one finds in seeds-hay the grasses and clovers that were sown in the original mixture, whereas meadow-hay is largely composed of permanent and indigenous species.

Even when grassland is sown down with the specific object of producing hay it is nevertheless necessary to give it a certain amount of grazing. If the season has been a suitable one a strong growth of grasses and clovers will develop soon after the nurse crop has been harvested, and unless this herbage is grazed off it will be destroyed by frosts during winter; moreover, the vitality of the plants will be

seriously checked. When there is a strong growth of young grass at this time it may be eaten down by almost any class of stock, though it should not be grazed too bare; but when the plants are small and weakly, as after a dry season, sheep, because of their close-grazing habits, may do a good deal of damage.

It is usual to rest the crop during the winter months, but it may again be stocked in early spring provided the animals are removed in time to allow the grass to shoot and to develop a good bulk for hay. The question of stocking in spring depends on the quality of the land; on a poor farm it may lead to a reduced yield of hay, while on rich soil it may be the only method of preventing the crop from becoming over-luxuriant and rotting in parts. Harrowing and rolling are frequently practised in spring, the former to break any surface "cap" that may have formed and to spread the droppings of the stock, if any, and the latter to give a better root-hold to the plants that have been thrown out by winter frosts; but rolling is unnecessary on land that has been grazed.

Once the hay is clear of the land, an aftermath of grass and clover may be expected, and this may be either grazed or made into a second crop of hay; indeed, on first-class soil, in suitable seasons, more than two crops of hay can be obtained. The taking of more than one crop of hay tends, however, to impoverish the soil and nullifies much of the good accruing from its "rest" under grass. If the land is down to grass for one year only, the herbage should be eaten bare before ploughing takes place. If wheat is to follow the grass the soil will have to be turned over by September, but in the case of spring oats the operation may be deferred until New Year, whereby a much longer grazing period will be obtained. Where the hay crop is to be followed by grazing for several years, the subsequent management will be similar to that of permanent pasture.

One of the most important considerations in the management of hay-land is its manuring. Where the hay constitutes the only grass in the rotation, every endeavour

must be made to encourage the leguminous part of the herbage—which is probably largely red clover—because not only does it produce the greatest bulk in the hay, but it has to be relied on to improve the soil for the subsequent crops. In certain cases where hay is grown for sale to horse feeders, clover is regarded as an undesirable constituent. Only a small quantity of clover is therefore sown, and its growth is not specially encouraged. Assuming that the soil has been supplied with lime at regular intervals (if this is not done the clovers will ultimately fail), the crop should be liberally treated with phosphatic manure, and a proportion of potash on all but the heaviest classes of land. This might be done by applying 3 cwt. of steamed bone flour, or an equivalent of ground mineral phosphate, and 2 cwt. of sylvinite per acre as soon as the stock is removed in autumn. These minerals will encourage the root development of the clovers and cause them to spread and produce a strong growth in the following spring. At the end of April, when the grass is beginning to produce its summer growth, a top dressing of 1 cwt. or more of nitrogenous manure, such as sulphate of ammonia, will almost certainly produce a profitable return. If the aftermath is to be grazed no further manuring will be necessary, but if a second crop of hay is to be taken another cwt. of nitrogenous manure per acre will stimulate the plants to produce a good bulk. While no more nitrogenous manure should be employed than is likely to give a return commensurate with the cost, the farmer may safely apply more mineral fertilisers than can be taken up by the hay crop, remembering that an excess will not be washed out of the soil but will help to improve the yield of the following cereal. Mineral manures can probably be more profitably applied to seeds than to any other crop in the rotation, because they have the indirect effect of increasing the fertility of the soil by encouraging the fixation of nitrogen.

Meadow-Hay.—Meadow-hay is obtained by setting aside a portion of the grassland of the farm, mowing it every year, and grazing the aftermath only. This is better practice than

mowing and grazing in alternate years, as the fullest development of top grasses suitable for hay, which is brought about by judicious manuring, does not produce the most profitable grazing. Although meadow-hay does not produce as much bulk as seeds-hay it is often more profitable, particularly on heavy, wet soil that is difficult to cultivate.

It is clear that if hay is taken off a meadow year after year, the productiveness of the soil must be gradually reduced, and some of the poorest grass in England is found on old meadows. It becomes necessary, therefore, to manure at a rate which will at least be sufficient to restore to the soil those plant foods removed in the crop. Mineral manuring is necessary for the grasses and the maintenance of a proportion of wild white clover in the herbage. But wild white clover is a procumbent plant which develops little top growth, and although it improves the quality of the hay it contributes little to the bulk, hence it should not be encouraged at the expense of the strong-growing grasses. One finds, therefore, that while permanent pasture may be maintained in good condition by the use of mineral fertilisers only, meadow-land should receive in addition a dressing of nitrogenous manure to encourage the gramineous herbage. On heavy, second-class land about 400 lb. of calcium phosphate, in the form of high-grade slag or mineral phosphate, plus 10 tons of dung per acre every third year, has given good results. On good land, capable of responding to more liberal treatment, a profit has been obtained by applying in alternate years—A. 10 tons of dung, and B. a mixture of 1½ cwt. nitrate of soda, 2 cwt. of superphosphate, and 3 cwt. of kainit, the dung and minerals being applied in autumn and the nitrate of soda in spring. Lime is of course necessary every few years, and should be applied in the form of slaked lime or ground limestone. A large amount of potash is removed in the hay crop, and if no dung is available for dressing the meadow, a fairly large proportion of this fertiliser should be included in the artificial manuring.

One of the chief reasons for the unproductiveness of many of our meadows is the extraordinary prevalence of

weeds. Yellow rattle, sorrel, dandelion, and ox-eye daisy are all very common, and, with Yorkshire fog and soft brome-grasses, may constitute almost the whole of the herbage. There are several reasons which may account for such degeneration: 1. The soil may be so poverty-stricken that good forage plants cannot grow; this happens when the land receives no manure for many years. 2. The excessive use of dung tends to make land weedy. This may be remedied by employing artificial fertilisers for a number of years, because these tend to reduce the number of species by encouraging some at the expense of others. 3. The late cutting of hay allows certain varieties to reach maturity and scatter their seed, and therefore to spread at the expense of later sorts whose reproductive shoots are cut down before the seed is ripe: Yorkshire fog, yellow rattle, and brome-grass may overrun a meadow when encouraged in this way.

Meadow-land should be given a good, hard harrowing in spring, followed by rolling. After the hay crop has been secured it should be grazed hard with a mixed stock of sheep and cattle. This removes the coarse and tufty herbage and helps to maintain in the grassland a proportion of clover and fine bottom grasses. When the grazing stock is removed at the beginning of winter, a chain harrowing should be given to spread the manure.

Hay-making.

Hay-making is the process of cutting, drying, and storing various kinds of herbage. As a rule grasses and clover are grown for hay, but many other crops such as lucerne, vetches, and mixed peas and oats are also converted into dry forage for the feeding of stock in the winter months. As grass mixtures, obtained either in the form of "seeds" from arable land or from meadows, form the most common source of hay, the following paragraphs refer in particular to this class of herbage.

When the moisture content of grass, which is about 80 per cent., is reduced to about 16 per cent., the material is sufficiently desiccated to prevent bacteria from bringing

about decay, and it is on this principle that haymaking depends. Theoretically it is possible to bring about the reduction in moisture without changing the composition of the grass in any other way, but practically something like 10 to 20 per cent. of the dry matter is lost in the process. It is therefore obviously wasteful to use hay for feeding purposes when fresh green fodder is available.

In the southern parts of England haymaking generally commences in the first week of June, though in a dry season the operation may be in progress before the end of May. In Scotland the crop is not usually ready until late June or July, but much depends on the situation and elevation of the farm. Meadow-hay is about three weeks later than seeds-hay.

The right time to cut hay is when the majority of the plants in the herbage have just passed the "bloom" stage, *i.e.*, when they have cast their pollen. At this time the plant has reached its maximum development and the greatest yield per acre is obtained. If cut earlier the herbage is more nutritious but the leaves are so tender that they become broken off in the making process, and the plants contain so much sap that they are difficult to dry; moreover, the yield is less. On the other hand, if the crop is cut later the food materials from the leaves and stems will have been partly transferred to the seed, and the tissues will be unduly hard, fibrous, unpalatable, and indigestible. During bad weather, however, it is better to allow the crop to stand than to cut it and risk loss due to weathering.

It is important to have no more hay cut than can be conveniently handled by the available staff of men and horses should rain threaten. The effect of rain on cut herbage is to wash out a large proportion of the soluble constituents, and the dampness brings on fermentation which causes a further loss of dry matter. Sometimes as much as a third of the weight of the crop is lost in these ways, and, moreover, the loss is almost entirely confined to the most nutritious and valuable part of the herbage. In the use of implements the farmer should avoid damaging the crop, the hay being handled no more than is absolutely necessary.

The tedder, though more thorough in its action, is more damaging than the swath-turner, and is very liable to break off the brittle leaves of clover: it should therefore be used only when a drastic treatment of the crop is essential.

Cutting is performed by means of a mower, which leaves the herbage lying on the ground in swaths, and the sequence and nature of the other operations depend on the luxuriance of the crop and the prevailing weather conditions. If the crop is small and the weather dry and sunny, practically no "making" is necessary, and the hay is sufficiently dry after one or two days' exposure to fit it for carting to the stack. As a rule, however, haymaking is not such a simple process. If the crop is heavy, and conditions for drying are bad, it may be necessary to use a tedder and to scatter the herbage over the surface of the field so that it may have every opportunity of exposure to the sun; but, unless weather prospects are particularly favourable, it cannot be left in this condition overnight for fear of damage by rain, and should be raked into windrows in the evening, or, if rain threatens, made into small cocks. In the case of an average crop in normal weather, however, it is customary to leave it in the swath for one or two days so that the upper layers become thoroughly dry, and then to invert the swath by means of a swath-turner so that the other side is exposed to the sun. If the weather conditions remain good, the hay should be fit to rake in about a day.

The next part of the process is to drag the hay into windrows by means of a horse-rake. Hay goes on drying in windrows where it is well exposed to the action of the air, and in many cases at this stage becomes fit to cart to the stacks; but in an average year hay is first put into cocks. If the herbage is still moderately damp the cocks, or heaps, should be made small, and two or more may be run together as the moisture evaporates. An endeavour should be made to put all cut hay into cocks if there are indications that the weather is about to break, and it should be borne in mind that the bigger the heap the less will

be the damage occasioned to the herbage by rain, but the more difficult the process of drying. If hay is cocked as a protective measure when it is half made, it may be necessary to scatter it again, when the weather improves, so as to complete its drying.

It is usual to judge the fitness of hay for carrying by its "feel"; but this can only be learned by experience in the field. It need not be absolutely dry, indeed very dry hay is so brittle that it breaks readily and many of the fine leaves are lost, and it is less palatable than hay having an appreciable degree of softness. If too damp, hay will ferment to a great extent in the stack and much of the dry matter will pass off in the form of gas; it may even be charred to such an extent that it becomes unpalatable. If very slightly heated, however, it becomes sweeter and very attractive to stock.

There are several methods of conveying hay to the stack. It may be forked from the cocks or windrows on to wagons, driven to the site of the stack and forked to the builders. Many devices have, however, been brought out for handling the hay and reducing the cost of hand labour. Hay loaders may be attached behind the wagons in order to raise the hay from the ground, so saving the cost of forking to the cart. Elevators and horse-forks may be used to transfer the hay from the wagons to the builders on the stack. If the stack can be built in the field, the carriage can be greatly simplified by the use of a sweep-rake for drawing the hay, whether it be in windrow or cock, right to the building site. The loose material left by the sweep is best raised to the builders by means of an elevator, the horse-fork being more suitable for dealing with well-compacted hay on a wagon.

In many of the wetter and later parts of our country, such as Scotland, the north of England and Ireland, hay is frequently built into ricks or pikes in the field as soon as it is sufficiently dry, each rick containing about a load or 15 cwt. Sometimes the ricks are built round wooden tripods, which keep the stack fairly open and facilitate the

drying of the grass. By their use hay can be stacked and therefore secured, although it is only half dry. These ricks or small stacks are large enough to afford the herbage ample protection from the weather, and small enough to obviate the possibility of over-heating. When the hay has remained in them for about a month it is built into large stacks or stored in a barn.

As is the case with cereals, hay stacks are built round and comparatively small in the northern and wetter districts, and very large and oblong in the southern counties, where the crop is got earlier and in better condition.

Grassland for Permanent Pasture.

Manuring.—In order to keep pasture in a high state of productiveness it is essential to replace losses which are brought about by grazing stock or by selling milk or its products off the farm. Fattening bullocks remove but small quantities of mineral matter and nitrogen from the land, but calves and young growing stock, which are building up bone and muscle, must necessarily tend to deplete the reserves of these substances in the soil. Sheep resemble young stock in exerting a continuous drain upon the soil, because not only are they nearly all growing or nourishing young, but they also produce annual crops of wool, a highly nitrogenous substance. In the case of cows a good deal of mineral matter and nitrogen is required for the nourishment of the growing calf, but much depends on the method of disposing of the milk. If butter only is sold and the separated milk fed to calves or pigs, the losses to the farm will be comparatively small; but the largest losses effected through the agency of live-stock take place when milk or cheese is sold off the holding. In all cases, however, the losses in pasture-land will be much less than in the case of meadows, and the amount of manure necessary to maintain the soil in fertility is correspondingly smaller.

In the building up of bone and muscle, phosphates, lime, and nitrogen must be obtained from the herbage by the stock. Potash is of much less importance, as animals retain

practically none of it in their bodies, and potash manuring is usually profitable only on light and peaty soils which will not grow leguminous herbage without its aid. As far as lime is concerned, much appears to depend on the availability of the lime reserves in the soil. Theoretically, lime should be applied to grassland at the rate of about 4 cwt. of slaked lime per annum, and when this is done dressings of 1 to 2 tons are applied at long intervals; but in many parts liming to this extent appears to be unnecessary, and the requirement of a particular soil is best found by trial on the spot. Although lime may improve the feeding quality of herbage without increasing its yield, as a rule liming will not be profitable on grassland that responds to phosphates. The use of lime is very effective where turf is thick, undecomposed and sour, or where in industrial districts the herbage is stunted owing to the influence of smoke. In supplying the soil with nitrogen it is usually possible to obtain all that is wanted from the air by the indirect method of encouraging the leguminous portion of the herbage by suitable manuring. Phosphates have to be supplied to make good the losses occasioned by grazing stock, and on most soils of the heavier class which are not markedly deficient in lime the correct use of phosphatic fertilisers has been shown to be the only method of developing and maintaining a high proportion of wild white clover in pastures. The manuring of such land therefore resolves itself into the proper use of suitable phosphates in order to encourage the maximum development of grasses and legumes, so as to ensure a continuous fixation of free nitrogen and save the farmer the expense of purchasing nitrogenous foodstuffs and manures. Clover will receive particular encouragement by this treatment, and clover has, bulk for bulk, a better feeding value than grass. But grass is stimulated by a dressing containing nitrogen, and if not kept well grazed tends to choke the clover down. Thus any treatment which encourages the grass at the expense of the clover reduces the productiveness of the pasture by diminishing the proportion of its most valuable forage plants. Consequently the feeding of cake to stock

on pasture, if unaccompanied by very hard grazing, is sometimes unprofitable because it adds nitrogen to the soil, and the good it does to the animals is more than counterbalanced by the harm it does to the clovers. Again lime sometimes does more harm than good, and this is thought to be because it so encourages nitrification that the grasses are liberally fed for a period and suppress the legumes. Grassland on certain light, peaty, and chalky soils gives no satisfactory response to dressings of phosphates; but in such a case there is usually some other limiting factor such as lack of potash or lime, and good results are got when the deficiency is corrected. Some poor worn-out grassland that is farmed under an extensive system will give no profitable return for mineral manuring but can be improved by supplying cakes, hay, etc., to the grazing stock.

It has been shown that the application of 10 cwt. of high-grade basic slag per acre, either with the seeds or when the grass begins to exhibit a demand for improvement, is the best all-round manuring for pasture, and if this is followed by 5-cwt. dressings every four years, the productiveness of the field can be maintained almost indefinitely. Recent work has shown that high-grade, finely-ground mineral phosphates are very little inferior to slag when applied in equivalent quantities to average land, and just as good on sour and damp soils where conditions make them more readily available. Fluorspar and certain other low-grade slags are inferior because of their lower solubility, equivalent quantities having about two-thirds the value of 40 per cent. slag, but this inferiority is much reduced on sour land. Superphosphate, either alone or mixed with steamed bone flour, gives good results on light and dry soils that contain plenty of lime.

Grazing.—Grazing animals have a profound influence on the nature of the herbage by keeping in check the larger and coarser grasses and preventing the small plants from being choked out. On the whole, the species which tend to multiply under grazing conditions are those that possess a creeping habit—*e.g.* wild white clover and bent grasses—and

those that produce an unpalatable flower head—*e.g.* crested dogstail, daisies, and buttercups.

The severity of the grazing throughout the season affects the persistency of the grasses, the yield and nutritive quality of the herbage, and the seasonal distribution of growth. Hard grazing in April when the plants are just beginning to grow has often an adverse influence on the persistency of grasses and may result in the spread of weeds; the effect is most marked on poor land in dry seasons. In considering the intensity of the grazing during the remainder of the season it should be borne in mind that herbage is most nutritious when young and freshly grown, and that this condition can only be maintained by grazing sufficiently hard to prevent the majority of the plants from developing flowering shoots. On the other hand, hard grazing reduces the yield of the grassland; but there is evidence that the superior nutritive qualities of the short herbage compensate for the smaller bulk. During summer there is a marked tendency for the plants to run to seed, and if they do so their growth for the rest of the season is greatly reduced. Where shooting is prevented at the normal flowering period the herbage maintains a fairly vigorous growth into late summer, and if the close grazing is continued the foliage will remain green and productive right into autumn and winter. If flowering cannot be checked by grazing, the mowing machine is suggested as a means of encouraging new growth.

Horses have the habit of resting on certain parts of the fields and grazing on others. The result is that some of the herbage becomes coarse and dirty, and patches are eaten down very close. For this reason a pasture wholly grazed by horses soon deteriorates. Not only will the grass keep its condition better, but the horses will thrive better when mixed grazing is resorted to, and the horses should be moved from one field to another several times during the season.

Sheep have the habit of selecting and grazing the finest and most delicate portions of the herbage, and neglect the strong-growing grasses or anything that tends to be coarse.

When land is grazed for prolonged periods by sheep alone it becomes very rough; bent and other inferior top grasses spread and dominate the better plants, and productiveness is reduced.

Cattle do not graze closely, and are unable to select the finest herbage; they graze much more uniformly than other classes of farm stock. Different classes of cattle, however, have different requirements as far as the pasture is concerned. Fattening bullocks must be given good grass and plenty of room to make a selection, or they will fail to make good gains and finish properly. As a consequence of this light stocking of the pasture, the less palatable herbage will tend to become coarse and will have to be got rid of by other means. Dairy cows are hard grazers, and can be relied upon to make a pasture uniformly bare. Store cattle resemble cows in their feeding habits, and rough Galloway or Highland two-year-olds will eat off coarse and withered herbage better than any other class of stock.

There can be no doubt that mixed stocking is best for grassland, and will result in a greater profit than grazing by a single species. Sheep and cattle respectively keep down the fine and the coarse herbage, and in the Cockle Park experiments this combined grazing produced almost double the live weight increase per acre obtained from sheep grazing alone.

In arranging a grazing system one of the best methods is first to put on the fattening cattle, follow this up by hard grazing with sheep and store cattle, and then spread the droppings by means of harrowing and give the field a short rest before repeating the process. On land that is heavy and liable to puddle, it is best to keep cattle and horses off the grass during the wet winter season. On the whole far more damage is done to grass by light stocking than by hard grazing, because if the herbage is once allowed to become coarse it forms a mat over the surface which practically prevents further development of fine grasses and clovers.

Intensive Treatment.—Recent work has shown that the

productiveness of grazing land can be greatly increased by the adoption of a system of intensive management involving the liberal use of nitrogenous as well as other manures, rotational grazing, and systematic cultural treatment. The following is a brief account of the system as applied to the grassland of a dairy farm:—The pasture is fenced into six or eight paddocks and water is laid on to each. In early winter the land is limed if necessary and is given phosphates and potash equivalent to about 4 cwt. of ground mineral phosphate and 3 cwt. of kainit per acre respectively. In January or February the first paddock is given a dressing of nitrogenous fertiliser equivalent to from 1 to 2 cwt. of sulphate of ammonia per acre, and thereafter, at intervals of about a week, each of the other paddocks in turn is given a similar dressing. In April, or when the herbage is almost 4 in. in height, the first paddock is ready for the milch cows, which, after being accustomed to green food, are turned on in sufficient numbers—say 10 per acre—to eat off the best of the grass in from three to seven days. The milch cows are then removed to the second paddock and their place is taken by "followers" such as dry cows, young and store stock, which eat the pasture bare. In turn each paddock is grazed first by the principal stock and then by the followers. As soon as the animals are removed from a paddock, harrows are employed thoroughly to spread the droppings, a second dressing of nitrogenous manure is applied, and then the herbage is rested until it is again from 3 to 4 in. in height and ready for a second grazing. If necessary, more nitrogenous manuring is given later in the season to keep up the yield in late summer; a total of over 100 lb. of pure nitrogen may be employed per acre per annum. If the herbage grows too fast for consumption in May and June, some paddocks should be mown for hay or ensilage.

The principal advantages of the system are that more than double the stock may be grazed on a given acreage, that the short herbage possesses relatively high nutritive properties, and that growth not only commences early in

spring but continues right into late summer. Care must be taken, however, to ensure that the herbage is grazed down before it becomes coarse, otherwise the clover and the fine grasses will be choked out. The system is most likely to be profitable on highly rented land that is capable of responding to liberal treatment; on poor land the increased returns are not as a rule commensurate with the cost of manuring, fencing, and watering.

Control of Weeds.—The most effective control of weeds in grassland is secured by careful stocking and judicious manuring, and if these factors are attended to the pasture is unlikely to become foul; drainage, however, is also necessary, and choked drains should be attended to at once. Dwarf weeds, such as daisies and plantains, can only be kept in check by manuring, which encourages the grasses and clovers to such an extent that the weeds remain stunted. Thistles should be cut when they are about 6 in. high, and the cutting has to be repeated as frequently as fresh stems appear so that the plants never flower: this ultimately leads to the exhaustion of the food reserves in the root-stocks and the thistles die. Yellow rattle can usually be checked by hard grazing, but also succumbs to cutting early in the season. Land that has been badly managed and is overrun with Yorkshire fog and brome-grass can hardly be improved without recourse to ploughing and re-seeding. Bracken may be checked by frequent cutting or spraying with 5 per cent. sulphuric acid in July. Bent grass and crested dogstail may tend to occupy too large a proportion of the ground, particularly where sheep have long been grazed alone, and may be checked by hard grazing with cattle or mowing for a few seasons. Whenever a patch of docks appears the plants should be dug out or they will spread rapidly by seeding.

Mechanical Treatment.—As is the case with meadowland, pastures are considerably improved by good hard harrowing, which tears out moss and lets air in about the plant roots. It is particularly important that really severe treatment with heavy harrows should be given before applying manures to thick springy turves, otherwise clovers

will have difficulty in spreading and will respond to the manuring but slowly. Coarse tufty herbage that is left over winter will check the development of young leafage in spring. Rank grass that cannot be grazed may be destroyed by burning about the beginning of March, or it may be removed by heavy stocking and hard treading with animals that are being artificially fed. In July or August unpalatable top-herbage should be cut down with a mowing machine. The rolling of pasture land is usually unnecessary, as the animals compact the surface layers of the soil very thoroughly by treading.

Improvement of Pasture.—The question of drainage is the first thing that must be given consideration, as no treatment will be of any avail if the soil is in a water-logged condition. The appearance of a field that requires draining has been described in Book I., Chapter III., and the farmer, from his knowledge of the soil and the situation of the field, must make up his mind as to whether this costly improvement is likely to be profitable.

Pasture improvement is largely effected through stimulating the growth of wild white clover by means of phosphatic manures, but the best results are obtained only when good varieties of grasses are also present in the herbage. Sometimes the quickest way to improve grassland is to plough down the old vegetation and start all over again, and if the field is capable of producing crops at a profit it may be put through a rotation, thoroughly cleaned, well manured, and seeded down again with a suitable mixture. The nature of the rotation will depend on local conditions, but in an extreme case, where even corn crops can only be grown at a loss, it is yet possible to re-seed by using rape as a nurse crop. When this is done the land is ploughed early, and limed if necessary, so as to give the old turf every chance to decay, and the mixture is broadcast with 3 to 5 lb. of rape on a finely prepared seed-bed in late spring. The rape grows rapidly and provides the young seeds with a certain amount of protection, but it must be thinly sown or it will develop a smothering effect, and

5 lb. per acre can be employed only on poor land where the plants grow to no great size. The nurse crop can be grazed down with sheep in autumn, by which time the grasses and clovers will be established. In a case of this kind phosphates are usually applied with the seed in spring.

If ploughing the pasture is unnecessary or impracticable, one or other of the following treatments is likely to prove effective:—

1. *Appearance.*—The herbage is worn out and exhibits every indication of lack of manuring. There are bare places through which the soil is showing, and the clover plants are scarce, small, and stunted.

Treatment.—On all except the lightest class of land a pasture in this condition should give an immediate response to a 10-cwt. per acre dressing of high-grade slag. The clovers will spread rapidly and cover the ground, and in a short time the grasses will respond to the improved condition of the field and grow more strongly.

2. *Appearance.*—The herbage is worn out as in case 1, but a minute examination of the pasture fails to reveal the presence of wild white clover.

Treatment.—Before slag can have any effect on a pasture of this kind it will be necessary to introduce the absent clover. Apply 10 cwt. of slag in winter, and early in May give the pasture a severe harrowing with a heavy implement so that the surface of the field is scattered over with torn-up soil. Choose a spell of damp weather and sow 1 to 2 lb. of wild white clover per acre in mixture with saw-dust or grass seeds to provide enough bulk to sow. Harrow, then roll the seed in with a heavy roller, and leave for a short time to enable the plants to establish themselves. This treatment is called renovation, and has often proved highly successful.

3. *Appearance.*—The herbage is poor in quality and contains few clover plants as in case 1, but the grazing has been neglected and the herbage is so rough in places that a dressing of slag has little chance of finding its way down to the soil where it can do good.

Treatment.—Before slagging can be considered it will be necessary to eat off the rough grass. The best animals for this purpose will be lean store cattle that have been running on a hill-grazing. If they do not at first readily eat the dead grass, a few cwt. of common salt scattered over the roughest patches will make the tufts much more appetising, and the cattle can be relied on to leave the field sufficiently bare for the purpose in view. A good hard harrowing will help matters after the grazing is over, and a full dressing of phosphatic manure may then be broadcast.

4. *Appearance.*—A thick turf of undecayed vegetable matter forms a dense mat over the surface of the soil; the turf is springy under foot; clovers are absent or very small, and there is every evidence that acid conditions prevail.

Treatment.—A field in this condition is obviously so sour that no treatment will be effective until normal plant decay is re-established by the removal of the acid conditions. Liming will have to be carried out, and probably a dressing of at least 2 tons per acre will be necessary. In extreme cases the addition of lime does not at once start the decay of the matted turf, and it would appear that a long spell of acid conditions has resulted in the elimination of the putrefactive organisms which ordinarily destroy dead tissues. If the failure of lime to have an immediate effect indicates such a state of affairs, a light top dressing of farmyard manure should be tried, as this introduces plenty of bacteria and may bring about the desired result. Once the dead matter has rotted away the subsequent treatment will depend on whether clover is present or not. If so, slagging should have a good effect, and if not, "regeneration" (renovation) will have to be practised also.

BOOK III

FARM LIVE STOCK

CHAPTER I

THE PRINCIPLES OF BREEDING

THE science of Genetics, as distinct from the craft of breeding, is of very recent origin; it dates from the discovery, in the year 1900, of Mendel's work. In the interval genetical theory has made rapid strides and already it has found important applications in the business of plant improvement. So far, it is true, the methods of the stockbreeder have been affected but little, but it is none the less important that he should study the science that underlies his art; partly because this will give him a clearer understanding of his problems and partly because practical applications of the new knowledge will certainly eventuate.

The Mechanism of Heredity.

In sexual reproduction, which is the normal process in all the higher animals, and is universal among farm live-stock, the individual develops from a fertilised egg or *zygote*, which is the product of the union of an ovum or egg cell produced by the female with a sperm cell produced by the male. The organisation of these bodies, as it can be seen under the microscope, has an important bearing on the theory of heredity.

The egg is a relatively large cell, containing a mass of protoplasm and yolk, together with a small nucleus—a clearly differentiated region with a characteristic structure. The sperm is a very minute motile cell with no yolk and very little cytoplasm (*i.e.*, extra-nuclear protoplasm), but containing a

nucleus that is similar in size and appearance to that of the egg. There is ample evidence that the bearers of the hereditary characters must be sought for in the nuclei of the germ cells. For one thing, the only portions of the egg and sperm that are comparable are their nuclei, and we know that, broadly speaking, the male parent has just as much influence on the characterisation of the progeny as has the female. The nucleus of a cell that is in normal growth, or is carrying out its ordinary functions, contains a complex network of threads of a readily stainable substance called chromatin. When, however, cell division is about to occur, the chromatin threads condense, thicken, and assume the form of a number of generally rod-like bodies called *chromosomes*. These chromosomes are constant in number for all the cells of the individual (with the significant exception mentioned below) and for all the individuals of a race. Moreover it can frequently be shown that each chromosome has a definite kind of individuality, for whenever particular members of a set can be recognised by size or shape, a group from one cell can be matched, member for member, with that from another. A further important fact is that the chromosomes occur in the body cells in pairs, and all the evidence points to the conclusion that of each pair, one member is derived from the male, the other from the female parent. In the ordinary type of cell division (Fig. 47) each chromosome splits longitudinally into two like halves; the latter are drawn apart to opposite poles of the dividing cell, the nuclear wall breaks down and two nuclei are formed, each containing a complete set of the divided chromosomes.

In the division that gives rise to the reproductive bodies —the ova or the sperms—the process is essentially different from that just described. The condensation of the chromatin into chromosomes takes place much more slowly, and when the chromosomes finally appear they are found to be united in pairs. The long preparatory stage is believed to have to do with an exchange of like parts between the paternal and maternal members of each chromosome pair. In any case the two members of each chromosome pair now separate,

a further division follows immediately, and four nuclei are produced. The essential point is that the nucleus of each cell contains only half the number of chromosomes that is characteristic of the body cells of the species. Of the four

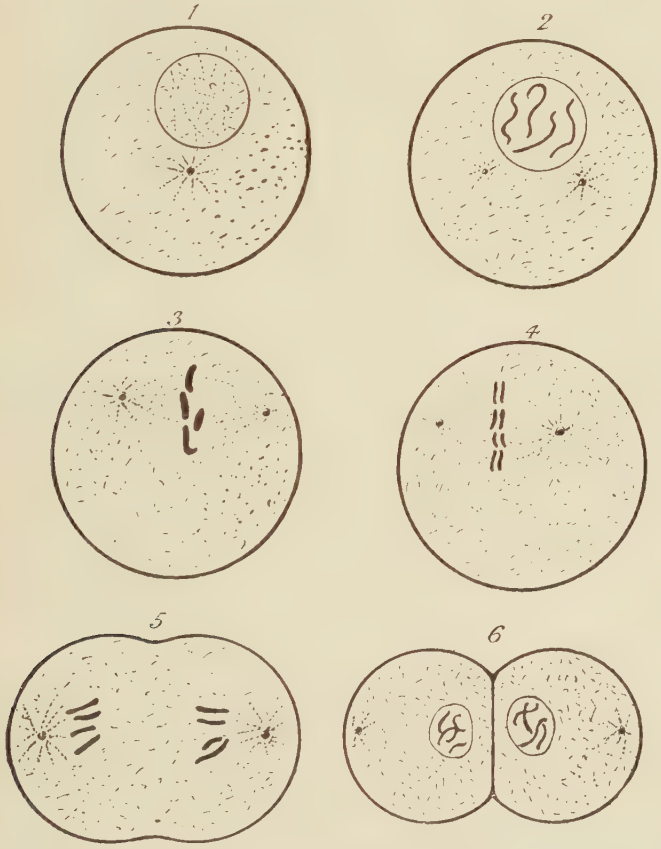


Fig. 47.—Ordinary Cell Division.

cells, each, in the case of the male, becomes a functional sperm (see Fig. 48). In the case of the female one becomes the functional egg, while the others are cast off as the so-called polar bodies, which can be looked upon as abortive eggs. When fertilisation occurs the sperm nucleus fuses with that

of the egg and the original or double number of chromosomes is restored.

A further interesting point is that there is frequently a characteristic difference between the set of chromosomes possessed by the male and by the female respectively. The one sex has a complete double set of chromosomes, the two members of each pair being like. The other sex has either one odd chromosome or else an unlike pair. Thus in the

FIG. 48.—The Reducing Division—Formation of reproductive cells in the male.

American fruit-fly, *Drosophila melanogaster* (see Fig. 49), the female has four like pairs of chromosomes, and, when reduction occurs, produces, so far as the chromosome content is concerned, only one kind of egg. In the male, three pairs of chromosomes and one member of the remaining pair can be matched in the female set, but the second member of the last pair is recognisable from the others by its shape, which is that of a rod bent sharply in the middle. The male thus produces two sorts of sperm cells in equal numbers, half containing the straight chromosome (or X chromosome as it has been called), and half the bent or Y chromosome. It follows that eggs fertilised by the first sort will produce females, since they will possess the constitution

symbolised by the formula XX; those fertilised by the second will develop into males since they will have the constitution XY. The chromosomes thus provide a simple mechanism for the determination of sex. Apart from this the facts just quoted are important in connection with what

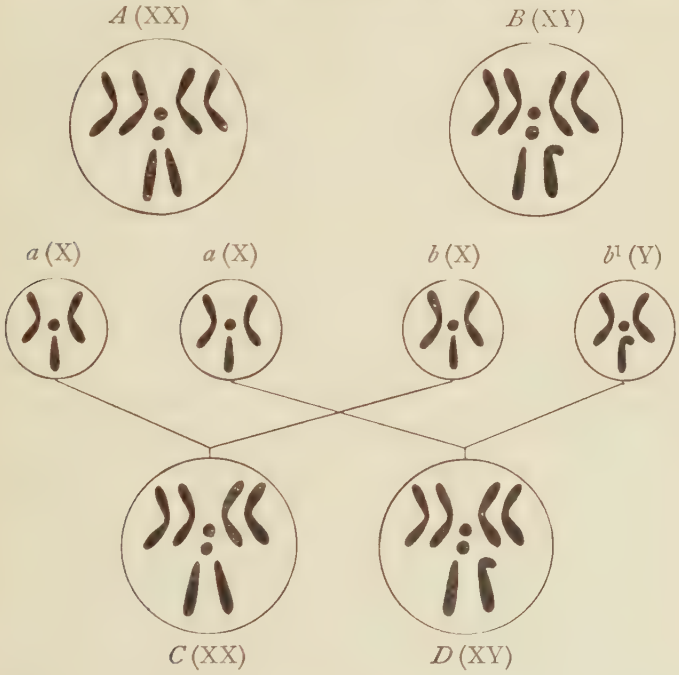


FIG. 49.—The Chromosomes in *Drosophila melanogaster*.

A, female; *B*, male; *a*, *a*, ova; *b*, b^1, sperms; *C*, female zygote formed by union of sperm *b* with egg *a*; *D*, male zygote formed by union of egg *a* with sperm b^1.

is called sex-linked inheritance, a peculiar phenomenon that arises from the circumstance that factors for other characters than sex would appear to be carried by the sex chromosomes.

The particular arrangement of the sex chromosomes just described is not universal. It is reversed for example in fowls, where the male is *homogametic* (producing but one sort of sperm so far as chromosome content is concerned),

while the hen is *heterogametic*, giving rise to two sorts of ova, male producing and female producing respectively.

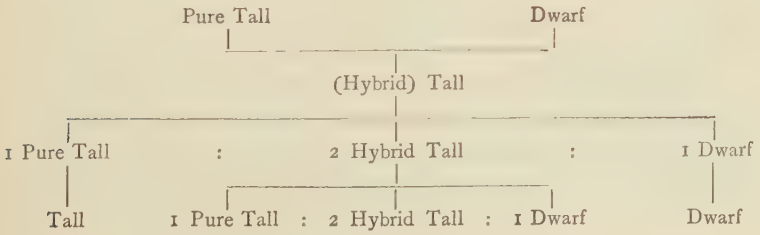
The Continuity of the Germ Plasm.

Past generations of biologists were much concerned with the question of how the heritable qualities of the animal got into its reproductive cells. Darwin, for example, imagined a process whereby samples of all parts of the body were collected and assembled in the eggs or sperms. Now, however, it is generally agreed that no such mechanism need be assumed; instead, we suppose that there is preserved, from the outset, a sample of the material from which each individual develops. When the fertilised egg begins to divide certain of the cells that it produces become specialised in one direction or another and collectively form the body or *soma*, which ultimately dies. But certain other cells are set apart, remain unspecialised, and later give rise to eggs or sperms. The germ plasm is in a sense immortal and the bodies of successive generations may be regarded as a series of temporary dwellings that it builds, and in which it finds protection and nourishment. So long as the germ plasm is thus protected and nourished, it ordinarily remains quite unaffected by accidents and vicissitudes that may leave deep impressions upon the body. The resemblance between parent and offspring arises not because this or that quality is directly inherited by the child from its parent, but because the child is produced in part from the same stock of germ plasm as the father.

Mendel's Law.

Such being the mechanism and such the general theory of heredity, let us now turn to some of the observed facts of inheritance. In 1865, Gregor Mendel, as a result of some crossing experiments with garden peas, was led to make an important generalisation regarding the manner in which parental characters are distributed among the progeny. Varieties of peas show a considerable number of definite

character differences—*e.g.* some varieties are tall, others dwarf; some have round seeds, others wrinkled, some green seeds, others yellow, and so on. Moreover, the plants are self fertilising, and varieties, as a rule, breed true to their own particular characters. Mendel's method was to cross two types showing some definite character difference; if the two varieties showed more than one such difference he considered each difference without reference to the others. He reared the hybrid plants and allowed them to become self-fertilised; in the next or second hybrid generation he classified the individual plants with reference to the original parental characters, and counted the members of each group. In one experiment, for example, Mendel crossed an ordinary tall variety with one of the well-known dwarf sorts, both varieties being known to breed true to their respective types. The first cross plants were tall like the tall parent—indeed, they somewhat exceeded the latter in height. These hybrid talls did not however breed true. On the contrary, when allowed to become self-fertilised, they produced tall and dwarf progeny in the proportion (roughly) of three of the former to one of the latter. Mendel's actual figures were 787 tall and 277 dwarf, or 73 per cent. and 27 per cent. respectively. When these second cross plants were tested individually (by making separate sowings of the seeds of each), it was found that all the dwarfs bred true. Of the tall second cross plants a proportion, about one-third, were found to produce nothing but tall progeny, while the remainder gave talls and dwarfs in the same ratio as did the first cross. These results may be summarised in the following scheme:—



The fact that the first cross resembled the tall parent, and showed no sign of the dwarf character, was expressed by Mendel by saying that "tallness" was *dominant*, and "dwarfness" *recessive*. Dominance, however, is by no means a regular phenomenon in crossing; and although all the characters dealt with by Mendel could be classified as definitely dominant or recessive, this can only be regarded as an accident. More recent experiments have shown that complete dominance is the exception rather than the rule; a hybrid commonly shows a condition somewhat intermediate between those of its parents. For instance, if a red-flowered variety of *Mirabilis jalapa* (Marvel of Peru) is crossed with a white, the hybrid bears pink flowers. If these are selfed and a second hybrid generation is reared the ratio obtained is 25 per cent. red, 50 per cent. pink, and 25 per cent. white. The reds and whites so obtained breed true, while the pinks of the second generation give the three types in the same ratio as did their parents. Thus whether or not there is dominance in a particular case, the general result is the same. When hybrids are self-fertilised or interbred they produce, with regard to any particular character, three types of progeny; the original parental types are each reproduced in one-fourth of the second hybrid generation, while the other half are hybrids like the first cross.

Mendel not only discovered this general rule of inheritance but he proposed an explanation of the facts. His hypothesis still stands. Subsequent research has brought out much evidence in its support, and has served to develop rather than to modify the original theory. Mendel knew nothing of chromosomes, but the facts regarding their behaviour fit in remarkably well with the phenomena that he observed, so that to-day we may best state Mendel's hypothesis in terms of the chromosomes. We assume then that a "factor" or "gene," controlling say the flower colour of the Mirabilis, is borne in one of the chromosomes of the species. A red-flowered plant will have a red-producing gene in both members of the chromosome pair concerned and, since each egg or pollen cell that it produces will receive one member of the pair, only

one type of reproductive cell will be produced. The white-flowered plant will contain "white" genes in the corresponding region of its corresponding chromosome pair, and all its reproductive cells will carry the white factor. When the two varieties are crossed it is obvious that the hybrid will have a pair of chromosomes that are unlike with regard to the gene for flower colour, one having the red factor and the other the

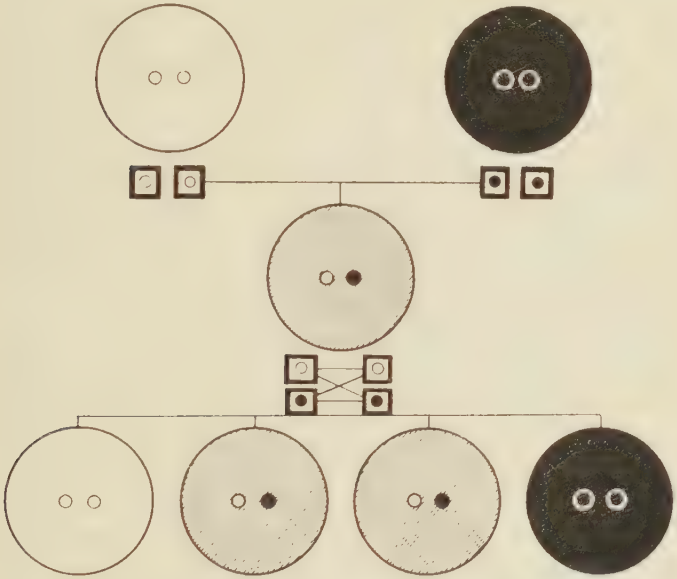


FIG. 50.—Cross between Red and White Varieties of *Mirabilis jalapa*.

The large circles represent the parent, first hybrid and second hybrid generations, and the small circles the genes. The squares represent the reproductive cells.

white. What visible result will be produced by such a combination is not capable of prediction, but in the present case we saw that the hybrid had pink flowers. Now the essential point of the theory is that the two genes do not intermingle, but remain throughout the life of the plant as separate and distinct entities. When the reproductive cells are formed, and the two members of the chromosome pair separate, half the ova and pollen grains will receive a chromosome containing

the "red" gene, while the other half will get one containing the white. The pink plant produces, then, reproductive cells that carry not a factor for the pink character, but that for either the original red or the original white, and the two classes occur in equal numbers. When the hybrid pink plants are selfed, fertilisation of either type of egg by either type of pollen grain occurs as a matter of "pure chance," so that the following four combinations are equally probable, viz.: "white" pollen grain with "white" egg; "white" pollen grain with "red" egg; "red" pollen grain with "white" egg; "red" pollen grain with "red" egg. The first combination will produce a white-flowered plant, the last a red, and the second and third pinks that are not distinguishable, since it is immaterial whether the red is introduced from the male or the female side. Thus is produced, it is suggested, the ratio of 1 red : 2 pink : 1 white.

The actual numbers obtained in Mendelian experiments are subject to chance variations, and do not, except by chance, give exactly the "expected" ratio. The numbers can be predicted only in so far that we can state the most probable result, just as we can in the case of, say, a series of tossings of a coin. Thus, if we make a hundred throws, the most probable single result is 50 heads and 50 tails, but the probability of obtaining 51 or 49 heads is only very slightly less, and so on through the whole series of possibilities. When, however, large numbers are dealt with, the ratio should approach very closely to theoretical expectation, and this has been the case in Mendelian experiments. Thus, for instance, one of Mendel's original experiments, dealing with cotyledon colour in peas, has been fourteen times repeated by different experimenters, and a total of 203,500 second hybrid individuals have been bred. Yellow colour is completely dominant to green, so that the expectation was 3 yellow, 1 green; or altogether 152,625 yellow and 50,875 green. The totals actually obtained were 152,824 yellow and 50,676 green, a ratio of 75·1 per cent. to 24·9 per cent.

If the hypothesis that has been outlined above is adequate,

it ought to enable us to predict the results of a mating between any two of the three possible types. For example, if we cross the pink (heterozygous[1]) *Mirabilis* back to the parent red form we should expect the following two combinations in equal numbers: "white" pollen and "red" egg cell, giving pink; "red" pollen and "red" egg cell, giving red. Similarly a cross of pink and white should give us pink and white progeny in equal numbers. Results of this sort have been regularly obtained.

Mendel's first law may therefore be stated thus. When a dissimilar pair of factors are brought together in crossing, they separate again when the hybrid produces its reproductive cells. The separation is clean and complete. The hybrid condition cannot be represented in the sperm or in the unfertilised egg. It can only be produced in the fertilised egg, and then by the union of an egg and a sperm that are dissimilar with regard to the factor in question.

Mendel's Second Law.

Mendel's second generalisation was to the effect that when two or more character pairs are considered simultaneously, each pair behaves without reference to the others. Since Mendel's time, as will be shown later, a very important group of exceptions to this law has been discovered and the evidence leads to the conclusion that these exceptions arise in cases where two pairs of genes are contained in one and the same pair of chromosomes. With this reservation, Mendel's second law is true. Take, for example, the results obtained in crossing a tall purple flowered variety of pea with a dwarf white-flowered sort. The tall condition is dominant to the dwarf and coloured is dominant to white. The first cross is therefore tall purple. If these plants are selfed and the succeeding generation reared we get, of course, the ratios of 3 tall: 1 dwarf and 3 purple: 1 white. But the two dominants do not necessarily go

[1] Heterozygous, since it received from its parents dissimilar factors for the character now being discussed, a "red" factor from the one and a "white" from the other.

together. On the contrary, the tall group will consist of purples and whites in the ratio of 3 : 1 ; the whites will consist of 75 per cent. talls, 25 per cent. dwarfs, and so on. Hence the combined ratio is obtained by algebraic multiplication of (3 T + 1 D) by (3 P + 1 W), giving 9 tall purple : 3 tall white : 3 dwarf purple : 1 dwarf white. It is obvious that very complex ratios will be produced when three or more character pairs are considered simultaneously. It was this complexity, apparent rather than real, that baffled all Mendel's predecessors, and it was Mendel's plan of dealing with one thing at a time that brought out simplicity and order from seeming chaos.

One or two somewhat odd cases must be described in which, though inheritance is strictly Mendelian, the results are complicated by reason of the effects produced by particular factors. One of the earliest discovered cases had to do with the inheritance of yellow coat-colour in mice. The first peculiarity of the case is that yellow mice never breed true ; in matings of yellows with yellows the young are about two-thirds yellow and one-third of other colours. Yellows are never produced from matings of two non-yellows. If yellow is mated with non-yellow the young consist of equal numbers of yellows and non-yellows. These facts indicate that yellow is dominant, but that all yellow mice are heterozygous for the yellow condition. If two such are mated, the expectation would be 1 pure yellow : 2 hybrid yellow : 1 non-yellow, and the only explanation of the facts is that the pure or homozygous yellow is incapable of life. This has recently found confirmation in the fact that in yellow × yellow matings a proportion of the embryos die in the easy stages of development. Why the homozygous yellow should be incapable of life beyond this early stage is not known, but it is interesting to note that even the hybrid yellows are not quite normal, being distinctly less hardy than non-yellows, and liable to become excessively fat. A further interesting fact is that many analogous *lethal factors*, leading to structural abnormalities or functional derangement of such an order as to render the individual

incapable of living, have been discovered in the fruit-fly and in several other species.

A very striking result of hybridisation was obtained in the course of some of the earlier experiments with sweet peas. Two white varieties gave a purple first cross. This occurrence can properly be classed as a reversion, since the wild parent of our cultivated forms is purple-flowered. These crosses, when left to become self-fertilised, gave progeny in the ratio of 9 purple : 7 white. In other crosses between two whites, other colours than purple were obtained in the first cross, and sometimes the second hybrid generation contained a mixture of coloured types, the proportion of coloured to white remaining, however, that of 9 : 7. Moreover the whites, when self-fertilised, always bred true; some of the coloured types produced only coloured progeny, while others gave one-fourth and still others seven-sixteenths of whites. The explanation of this case is that colour is produced only in the presence, simultaneously, of two dominant factors. One of the white varieties contains the first of these factors but lacks the second; the other has the second but lacks the first. The first hybrid thus contains both dominants and is coloured. In the second hybrid generation we get as usual a 9 : 3 : 3 : 1 ratio, the last three classes lacking respectively one or other or both dominants, and hence being white. Many implications of this theory have been tested, and the expected results obtained. The occurrence of different colours in the second hybrid generation is explained by the fact that white sweet peas may carry various factors capable of modifying colour, although in the absence of the colour factors themselves, these can have no visible effects.

Another case of "reversion on crossing" was found in mice. In certain cases when black and white mice are mated, the first hybrid generation is black, and the second gives the normal monohybrid[1] ratio of 3 black : 1 white. Black thus behaves as an ordinary dominant to white.

[1] A monohybrid is one produced by the mating of two individuals that differed one from the other in respect of a single character only.

Sometimes, however, the first hybrids between black and white are of the wild grey or "agouti" colour, and when these are interbred the ratio obtained is 9 agouti : 3 black : 4 white. Here, again, a completely satisfactory explanation has been offered. There is one dominant factor that produces colour, its recessive giving the albino or white condition. When a coloured variety is crossed with a white, the first generation is coloured, and the second splits up in the proportion of 3 coloured to 1 white. But there are other factors that determine the sort of colour, and these may be carried by white strains although producing in them no visible effects. Agouti is dominant to black, as can be demonstrated by crossing these two colours. If a white mouse happens to carry the dominant agouti factor, its crosses with blacks will be agouti—the hybrids obtaining the colour factor from the one parent and the agouti from the other. When these are interbred they should give 3 coloured to 1 white, and the coloured progeny should consist of "agouti" and black in the ratio of 3 : 1. Thus is produced the ratio of 9 agouti : 3 black : 4 white. Then also the whites should consist of 75 per cent. "disguised agouti" and 25 per cent. "disguised blacks," an expectation that has been confirmed by further matings.

A long series of similar cases might be described ; none of them however constitutes an exception to Mendel's two laws. The complications arise out of the visible effects of the factors, and the factors themselves behave in the normal way.

Linkage.

It was not until some ten years had been spent in active Mendelian investigation that any new principle was discovered. The first cases that failed to conform to Mendel's second generalisation were found in sweet peas. In one of these cases a variety with purple flowers and an ordinary erect standard petal was crossed with another having red flowers and a hooded standard. It was previously known that purple behaved as a simple dominant to red, and that

the erect standard was a simple dominant to the hooded. The first hybrids were purple erect, according to expectation. Had the case been normal the second hybrid generation should have consisted of the four possible combinations in the proportions—9 purple erect : 3 purple hooded : 3 red erect : 1 red hooded. The actual numbers obtained were—2036 purple erect : 12 purple hooded : 10 red erect : 654 red hooded. The numbers show that the two dominant factors on the one hand, and the two recessives on the other, have somehow "stuck together" in a great majority of cases. The numbers, in fact, strongly suggest the simple ratio of 3 : 1—three double dominants to one double recessive. But the other two classes, each containing one dominant only, do occur though relatively very rarely.

When the cross was made between two parent plants with the same characters in the opposite combinations the result was quite different. Purple hooded crossed with red erect again gave a purple erect first cross. In this case, however, the second hybrid generation consisted of—2969 purple erect : 1369 purple hooded : 1441 red erect. The fourth possible class, *i.e.*, the double recessive red hooded, did not occur at all. Here, again, the results suggest a simple monohybrid ratio—viz., one-fourth like each of the original parents and one-half like the first cross. It is obvious from the second experiment that the case is not one of attraction between any two characters as such. The point is that, however the characters are combined in the original parents, these combinations tend to persist and to reappear in the second hybrid generation. The old combinations are broken, and new combinations made only in a small minority of cases.

This phenomenon of *linkage*, as it is called, remained without a satisfactory explanation until it was cleared up by the work of Professor Morgan and his associates on the fruit-fly (*Drosophila melanogaster*). This fly has provided exceptionally favourable material for investigations in heredity. It breeds very rapidly, and is easily and cheaply reared in large numbers. It shows a great number of alternative characters—fully 200 have already been found—

and finally it has, as we have already seen, a small number of chromosomes—four pairs.

The theory that has been devised to account for linkage is this. Each factor or gene has a definite place or locus in one or other of the chromosomes, and the arrangement of the genes is linear, that is to say, the chromosome consists of a group of genes arranged like beads on a string. Now, if two pairs of characters are represented in different pairs of chromosomes they will be transmitted quite independently of each other. If, however, we have two pairs of genes in the same pair of chromosomes, they will show some degree of linkage, *i.e.* will tend to remain in pre-existing combinations rather than to form new ones. Further, if two genes have their loci close together in a chromosome, the linkage between them will be close, and the farther apart the loci, the looser will the linkage be. Several implications of this theory have been tested. One is that, when the heritable characters of the race have been fully investigated, it should be found that there is a group of linked characters corresponding to each chromosome. In *Drosophila* this has been fully confirmed. Here there are two pairs of large ordinary chromosomes, one pair of small ordinary ones, and a pair of sex chromosomes. There are four corresponding groups of linked characters, two large and one small group showing ordinary linkage, and one group showing sex linkage. Similarly, in the sweet pea, there are seven pairs of chromosomes and the heritable characters fall into seven linkage groups. Again, if we determine the degree of linkage between any gene and any two others in the same group we fix its locus, and are then in a position to predict its linkage relationships with any other genes whose loci are known. Such predictions have been made, tested, and confirmed. In the case of *Drosophila* a complete plan of the germ plasm has been drawn, showing the exact point at which each gene occurs in the chromosome to which it belongs.

Linkage is explained by assuming some mechanism by which the two members of each chromosome pair exchange

homologous parts. This is thought to occur just before the reducing division which gives rise to the reproductive bodies. It will be obvious that if no such interchange took place we should have complete linkage between all the genes in a chromosome. If, on the other hand, the two chromosomes were resolved into their component genes, and if the new chromosomes were built up by a chance reassortment of the

FIG. 51.—Diagram to illustrate crossing-over in *Drosophila*.

a, egg; *b*, sperm; *c*, female zygote. The black dots represent genes derived from the female parent, the white those derived from the male. *d*, *e*, *f*, and *g*, pairs of egg cells produced by *c*, showing various distributions of the genes.

genes, there would be no linkage at all. The actual process, it seems, is neither of these. The two members of each pair of chromosomes do exchange homologous parts, so that linkage is not absolute, but the exchange is one of considerable blocks of chromatin, so that adjacent genes tend to remain together in a great majority of cases. This process, as it has been imagined (for it cannot be demonstrated microscopically), is illustrated in Fig. 51. In some cases the

parental chromosomes separate without interchange of genes —or, as it is expressed, without *crossing-over*. In other cases one break—single crossing-over—occurs, and in still others there is double crossing-over. The points at which breaks occur are settled by pure chance, except that two breaks in close proximity to each other are very rare.

FIG. 52.—Redistribution of Chromosomes in the male *Drosophila*.

a, egg; *b*, sperm; *c*, fertilised egg; *d*, *e*, *f*, and *g*, four pairs of sperms showing some of the possible reassortments of the chromosomes. There is no crossing-over.

A curious fact is that in the male *Drosophila* there is no crossing-over. Linkage is absolute. The parental chromosomes separate in their original forms as is shown in Fig. 52. The reason for this is not understood. It is known, however, that in other species, crossing-over occurs in both sexes.

Sex-Linked Inheritance.

A complication is introduced in the transmission of certain characters owing to the fact that their factors are

carried by the sex chromosomes. In *Drosophila* the straight sex-chromosomes, or X-chromosomes as they are called, of which the female has two and the male only one, are in all respects like the ordinary chromosomes. The bent or Y-chromosome—the second sex chromosome in the male—is something quite distinct, for the results of countless breeding experiments have failed to disclose the presence of any genes thereupon. For the present it can be regarded as the "dummy" mate of the single functional sex-chromosome in the male. It seems quite certain that it does not carry those factors which are resident in the X-chromosome. The result is that whereas the female has a complete double set of genes, the male has only a single set of those that occur in the X-chromosome. An example of how this works out may be quoted. In *Drosophila* red eye colour is dominant to white, and the factors for these characters are carried in the sex-chromosomes. In Fig. 53 the transmission of the character is worked out, the gene for eye colour being represented by the circle in the X-chromosome.

When a red-eyed female is mated to a white-eyed male the progeny (of both sexes) are red-eyed. If these progeny are interbred we get the usual ratio of three red-eyed : one white-eyed in the second cross. But it is significant that all the white-eyed individuals are males.

When the cross is made in the opposite direction, as is shown in Fig. 54, the result is entirely different. A white-eyed female mated to a red-eyed male produces red-eyed females and white-eyed males. The sons take the eye colour of the dam, the daughters that of the sire. This so-called criss-cross inheritance is a common phenomenon in sex-linked cases. If the first hybrids are interbred they produce, in equal proportions, red-eyed females, white-eyed females, red-eyed males, and white-eyed males. The mechanism will be understood by reference to Fig. 54.

Several analogous cases occur in poultry with the difference that here it is the male that has the two like, gene-bearing chromosomes. Whether the hen has only one sex chromosome, or whether it has a second "dummy"

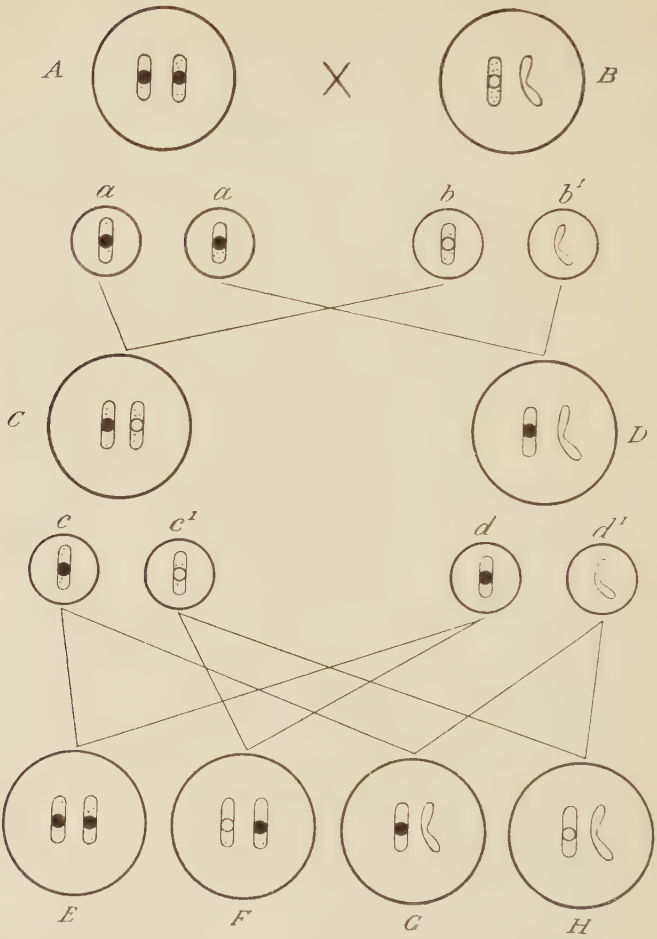


FIG. 53.—Inheritance of Red and White Eye in *Drosophila*.

A, and *B*, red-eyed female and white-eyed male. *a*, *a*, eggs; *b*, b^1, sperms. *C*, and *D*, first hybrid generation consisting of heterozygous red-eyed females and red-eyed males. *c*, and c^1, eggs; *d*, and d^1, sperms. *E*, *F*, *G*, and *H*, the four types in the second cross, viz.: *E*, homozygous red-eyed female; *F*, heterozygous red-eyed female; *G*, red-eyed male, and *H*, white-eyed male. Only the sex chromosomes are shown. The gene for red eye is represented by the black circle in the X-chromosome, that for white eye by the white.

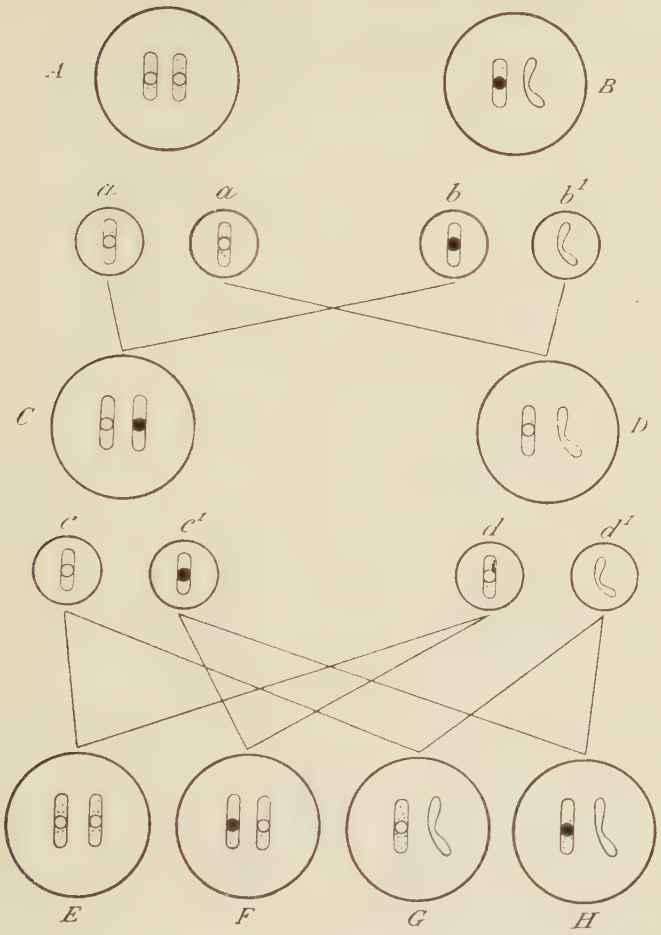


FIG. 54.—Inheritance of Red and White Eye in *Drosophila*.

A, white-eyed female ; *B*, red-eyed male. *a*, *a*, eggs ; *b*, b^1, sperms. *C*, and *D*, first hybrid generation—heterozygous red-eyed female and white-eyed male. *c*, and c^1, eggs ; *d*, and d^1, sperms. *E*, *F*, *G*, and *H*, four types in second hybrid generation. *E*, white-eyed female ; *F*, heterozygous red-eyed female ; *G*, white-eyed male ; and *H*, red-eyed male. Only the sex chromosomes are shown.

member like the Y-chromosome in *Drosophila*, has not been established. In any case it has only a single set of the sex-linked genes. The result of this condition of affairs is illustrated by the behaviour of the barred pattern of the

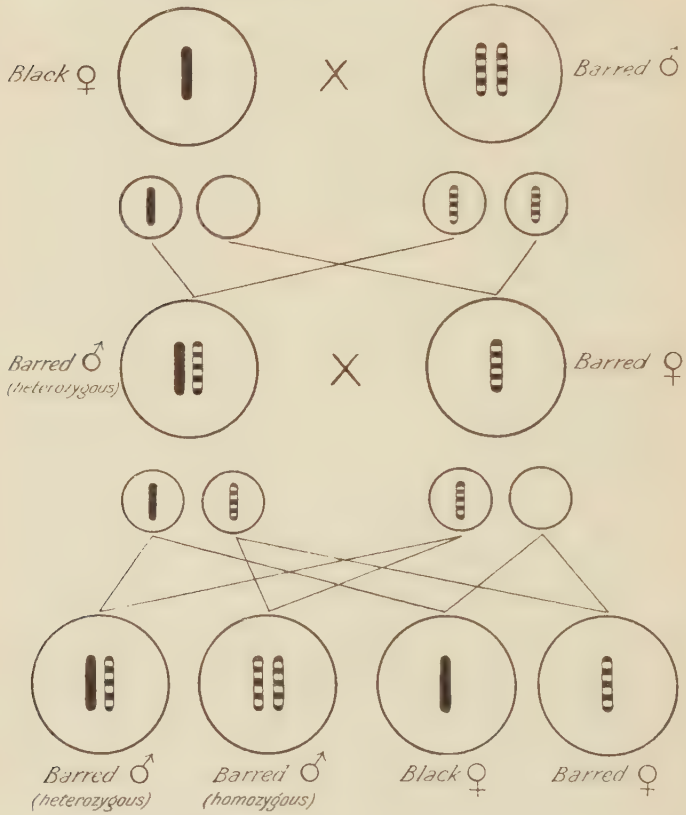


FIG. 55.—Inheritance of Barred Pattern in Fowls.

Barred Rock, which is dominant to black, and sex-linked. If a pure-breeding barred cock be mated to black hens, the progeny are all barred. In the second generation, the males are all barred and the females half and half as to colour. When the cross is made in the opposite direction —black cock with barred hens—the male chicks are barred

and the females black (criss-cross inheritance). In the second hybrid generation we get the four classes—black males, barred males, black females, and barred females in equal numbers. The mechanism is illustrated in Figs. 55 and 56.

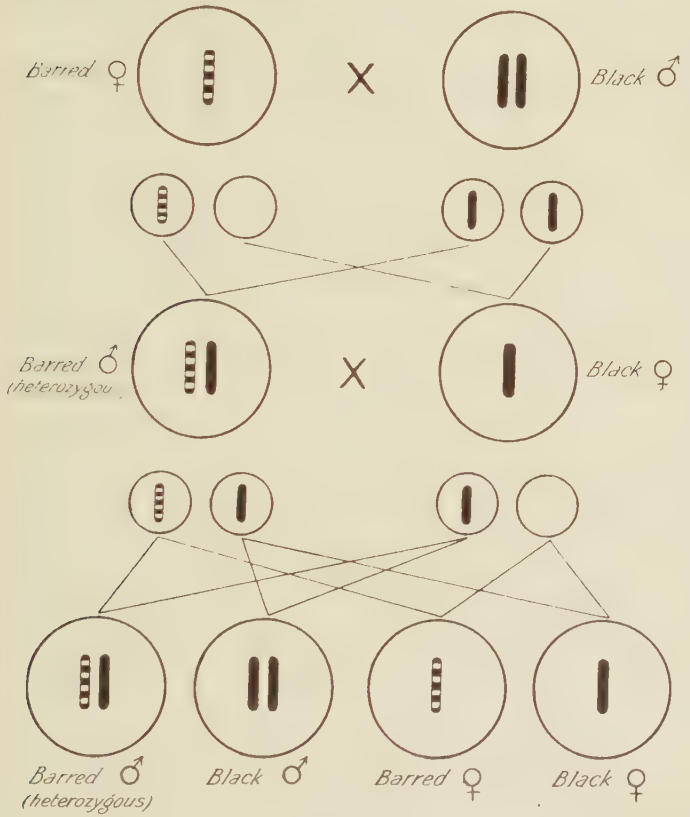


FIG. 56.—Inheritance of Barred Pattern in Fowls.

The explanation of all sex-linked cases is essentially the same. One of the sexes—the male in the case of the fruit-fly and the female in that of the domesticated fowl—has only one functional or gene-bearing sex chromosome. This it obtains in every case from its parent of the opposite sex. Thus all the sex-linked characters of the male *Droso-*

phila are inherited from its female parent, and all those of the hen from its male parent. The other sex has a pair of gene-bearing chromosomes, one derived from either parent, and therefore the normal complement—a double set—of the sex-linked genes. Its visible characters, in the event of the genes being different, are determined by dominance.

The importance of sex-linked characters is probably considerable. The pathological condition in man known as hæmophilia or "bleeding" is inherited in exactly the same manner as the white eye in *Drosophila*. In poultry one of the factors for egg production behaves like that for the barred pattern—*i.e.* it can be inherited by a hen only from the cock, and can be transmitted by her only to her male progeny.

We may now summarise our general conception of heredity. The hereditary characters of an animal are determined by a double set of factors or genes, one set derived from either parent. The sole exceptions to this rule are the sex-linked characters, which, in one or other of the sexes, are represented by single genes only. Ordinarily each visible character is the resultant effect produced by a pair of genes, whether the two members of the pair be like or unlike; sometimes the effect of one gene is so strong as completely to mask that of its fellow (dominance). When the individual produces its reproductive cells, and the chromosomes are reduced to half their original number, each egg or sperm cell receives either the one or the other member of each pair of genes, that is, it receives a single set. The mechanism controlling the distribution of the genes between the reproductive cells is such that certain pairs assort quite independently of others. This happens, we suppose, when they are situated in different chromosomes. There is, however, a tendency, definite and measurable in particular cases, for certain genes to stick together in pre-existing combinations (linkage). This, it is believed, is due to their occurrence in one and the same chromosome. Linkage, however, is normally only partial, so that the

chromosome cannot be regarded as a permanent or immutable assemblage of genes. There is, we believe, an interchange of parts between the paternal and maternal members of each chromosome pair, occurring probably just before the reducing division. But this interchange does not amount to a complete breaking down into individual genes, with random reassemblage of the latter into new chromosomes; it consists of an exchange of large fragments, each containing a considerable number of genes. The arrangement of genes in the chromosome is linear, and the degree of linkage between any two is determined by their distance apart in the series.

The heritage of a breed or race consists of the sum total of unit characters represented in the chromosomes of its individual members. The great bulk of observed variation between individuals of the same race (in so far as it is not due to conditions of nurture), is due to the process of biparental inheritance. This involves a combination, in each individual, of two sets of genes, one derived from each parent, and a reshuffling of these before they are handed on, in the germ cells, to the next generation. A race will breed true to all its characters only when each and every pair of genes consists of two identical members, *i.e.* when the maternal set of genes is exactly matched by the paternal.

Pure Lines.

It is worth while to look into this last hypothesis and see whether it will stand the test of experiment. The effect of biparental reproduction is to maintain a large number of characters in the heterozygous condition, and thus to produce a large amount of variation. In fact the whole significance of sexual reproduction seems to be that it makes possible a great series of character combinations, and thus gives the race as a whole the power to adapt itself to changing conditions. Among higher animals, therefore, we cannot expect to find true breeding strains unless we employ artificial means to produce them. Many

plants, however, have abandoned biparental reproduction, resorting either to vegetative methods or else to self-fertilisation. In either case we get rid of the complexities produced by the reshuffling of genes in each successive generation, and therefore we should expect to find fixed, true breeding strains. Such variations as occur within the strain must be due to causes other than heredity—*i.e.* to environmental causes—and should not be transmitted. This theorem has been put to the test in many experiments, and the results, in every case, have been in agreement with it. For example, if we take a single bean plant, descended, as normally it would be, from self-fertilised ancestors, it will produce a group of progeny having strictly the same hereditary characters as itself. Such a group of progeny, constituting what is called a *pure line*, is fixed, because all its members have the same set of characters in the homozygous condition. Selection within a pure line accomplishes nothing, because selection can only produce results where hereditary differences exist. Cross-fertilisation between plants of the same pure line is likewise without effect, for it amounts to nothing more than a combination of like with like. We are therefore justified in concluding that, as a rule, the individual genes remain constant from one generation to the next, and that the bulk of observed variation among the members of a breed or race is due to reassortment of unit characters, and not to any change in the unit characters themselves. This is important from the practical point of view, for it implies that there is a definite limit to the possibilities of selection. When we have obtained a certain combination of characters, all in the homozygous condition, we get no more variations of hereditary value, and hence further selection is a ploughing of the sands.

Such is true in the main; the units that compose the hereditary material are of definite constitution, and normally they remain constant. But occasionally, for reasons that are not understood, the genes do change. And when change occurs it is of the nature of a definite step; the new character is fully as constant as the old, and behaves as a Mendelian

alternative to it. Such sudden and definite changes in the hereditary material are known as *mutations*; they have been seen to occur in most species of plants and animals that have been kept under continuous and close observation; they are not necessarily connected with sexual reproduction, vegetative sports being relatively common. Sometimes they are obvious and startling, more often they are to be detected only upon close scrutiny; and it is certain that many have passed unobserved or have not been distinguished from the ordinary sort of variation, due to recombination of factors. In any case, mutations cannot as yet be produced at will, nor can their direction be controlled by any known method. All that the breeder can do is to watch for their occurrence and to perpetuate such as happen to prove of use. They must still be regarded as purely accidental. In general they occur only rarely, and of those that have been observed only a small minority have been of economic value. Yet their importance in the mass has been very great.

Live Stock Improvement.

The business of the constructive breeder—of him who sets out to improve his herd rather than merely to multiply it—is to build up a certain combination of valuable hereditary characters, that is, to produce a good type of animal that will "breed true" to its good qualities. Obviously the first essential is a definite object, a clearly conceived ideal type. Moreover, this ideal type should be no mere arbitrary standard of points, but should be laid down with regard mainly to economic considerations; that is to say our ideal animal should be that which will convert its food into meat or wool, milk or work, as the case may be, with a maximum of efficiency.

In certain cases it is easy to devise a simple and direct test of economic worth. It is so, for example, in the case of milk or of wool production because it is possible in both instances to determine both the yield and quality of the produce and to take such determinations as a basis for selection. The usefulness of a work animal is more difficult

to assess, because no final judgment can be reached until the end of its working life. With meat-producing animals again no information can be obtained on such important points as the quality of the meat, or the proportion of carcase to offal, until the animal has been slaughtered. In general, however, any direct test is preferable to a mere inference based on the animal's outward appearance, and there is an increasing tendency to apply such direct tests wherever possible. With pigs, for example, prolificness can be recorded and the milking capacity of a sow can, for practical purposes, be sufficiently measured by determining the live-weight increments of her piglings. The efficiency of the individual animal in converting food into meat can be expressed as a ratio between its weight increment and its food consumption, and even on such a matter as the quality of the meat of a breeding animal inferences can be drawn with some degree of certainty if a few of its litter brethren or its progeny be fattened and slaughtered.

When Bakewell,[1] the great pioneer breeder, started the improvement of British live-stock about the middle of the eighteenth century, the farm animals of the country were of very mixed type, and of a low average standard of merit. Certain local types were distinguished by peculiarities of size, prevailing colour, etc., but there were no breeds in the modern sense. In all these local types there seems to have been a great amount of variability with respect to useful qualities. Probably there were many individuals with one or other good quality, and occasional specimens showed chance combinations of several valuable characters; but ancestry was mixed and transmission apparently very irregular. The initial step in the improvement of each breed in turn, by one improver after another, has been to collect a herd or flock of the best individuals of the local type, and so to get possession of all the qualities that it was deemed advisable to perpetuate in the improved breed.

[1] Robert Bakewell of Dishley in Leicestershire, *b.* 1726, *d.* 1795, originator of the improved Leicester sheep and the improved Longhorn cattle, and breeder of cart horses and pigs.

If it happened that several of these characters could be obtained already combined in one individual, then the work of building up the desired combination would be rendered less intricate and tedious. But the main point is that the breeder could not expect, except as a rare piece of good fortune, to get any actual change in the individual unit characters with which he started—a favourable mutation. And hence the real essential in the foundation of a herd was to get together as many good characters as possible, even if this involved the introduction of some bad. For bad characters could be "bred out," whereas there is no known method of producing good characters *de novo*. Apparently Bakewell, when he laid the foundations of his Leicester flock, succeeded in gathering together all the characters that were essential to the making of a good long-wooled sheep, mixed up as they were with a greater number of undesirable qualities. On the other hand, his work with the Longhorn cattle of the Midlands was destined to comparative failure, apparently because elsewhere, in the valley of the Tees particularly, there was a better class of raw material—a local type of cattle among which there lay scattered a set of more valuable unit characters.

Having started on a basis sufficiently wide to ensure the inclusion of all the characters desired, the breeder proceeds, by successive matings and selection of the progeny, to weed out undesirable characters, and to combine the good qualities first in an individual or two and finally in a true-breeding strain. This process, it is true, has never yet been carried to the point of complete or final success, yet so much progress has been made that it is important to survey the methods by which it has been achieved.

Mass and Pedigree Selection.

The simplest form of selection is what is termed mass or phenotypic selection—the choice of breeding-stock on the simple basis of individual merit. The application of this process has given very different results according to the kind

of characters to which it has been applied. Obviously the degree of success attained will depend on the accuracy with which the constitution of the germ plasm is reflected in the visible or measurable characters. If a certain visible character represents a certain definite and pure (homozygous) condition in the germ cells then we are on perfectly safe ground. Thus, if we wished to obtain a race of single-combed fowls from a mixed population, a system of mass selection would give immediate and completely successful results, because we know that a single-combed fowl can have in its germ cells nothing but the "single" factor in the homozygous condition. For various reasons, however, the visible characters of the animal may be unsatisfactory, or even quite misleading, as a guide to the qualities that it is capable of transmitting. Characters like egg-production in fowls or milk-production in cattle are determined in part only by heredity, being influenced to a very marked extent by the conditions of "nurture" in the widest sense. Even when, in the case of a milch cow, we calculate the allowances for the grosser effects of age, time of calving, feeding, etc., we are left with a multitude of varying environmental conditions whose total influence it is impossible to assess. We must therefore proceed on the assumption that milk-yield is in large measure a matter of accident or "pure chance," and is only in part determined by heredity.

Even when a certain desirable quality is known to be solely a matter of heredity, mass selection often fails to give the desired results. This happens if the character in question is dominant to a corresponding undesirable condition. Thus, for example, in cattle the red colour is recessive to most others, and is completely dominant to none; hence reds breed true, and mass selection is immediately successful in establishing a true-breeding red strain.[1] With Angus cattle, on the other hand, the recognised black colour is completely dominant to red, *i.e.* there is no visible difference

[1] Certain types of white flecking or "broken colours" are recessive to whole colour, so that a whole red colour could not be readily fixed by mass selection.

between the homozygous black, which breeds true, and the black × red heterozygote which throws reds. The consequence is that red calves occasionally turn up in most herds, even though their ancestors may have been black for generations.

There is still another set of circumstances in which simple selection fails to accomplish anything. This happens when a particular quality is due to a hybrid condition of the germ plasm. Thus the pink colour in *Mirabilis*, the blue of the Andalusian fowl, and very probably also the blue-grey colour in cattle are due to a heterozygous condition, and it seems that one might breed from any of these types for countless generations and still be no nearer to a true-breeding strain.

Pedigree, when rationally used, forms a valuable aid to the breeder in his work of selection. Pedigree must never be regarded as an end in itself, *i.e.* individual merit must always be considered first—but the two taken in conjunction are undoubtedly a far better guide than either considered alone. The essential questions that a breeder should ask himself in attempting to evaluate a particular pedigree are (1) What was the average merit of the animal's immediate ancestors; and (2) what evidence is there that their good qualities were regularly transmitted from generation to generation? If we have a good individual, the progeny of good and true-breeding parents, it is probable that it will transmit its good qualities. The commonest error in the interpretation of pedigrees is that of attaching undue importance to far-back ancestors, and in particular to descent in the direct female line from particular "foundation females." It is quite certain that the average influence of any single animal in even the third or fourth ancestral generation is very slight indeed, and it is doubtful whether in practice there is much to be gained by looking back beyond three or four generations.

Genotypic Selection.

The third and by much the most effective method is what the biologists call *genotypic selection*, that is to say, selection on the basis of breeding ability, as determined by actual tests. The special value of this system arises from the fact that it enables the breeder to form a far truer estimate of the hereditary characters than he can do, either on the basis of individual merit alone or on the dual basis of individuality and pedigree. We may illustrate the method by reverting to the previous illustration of the red Aberdeen Angus. If it were a matter of prime importance to get rid of the red colour once and for all, the essential thing would be to breed from parents that were homozygous for black colour. If both parents were homozygous blacks, then the calves would all be homozygous blacks. But even if we made sure of one parent only, we should, for the time being, prevent the appearance of reds, and by continuous breeding from homozygous black on one side, we should very quickly reduce the number of the black × red hybrids in the herd. In practice this is all that could be done, because it is impracticable to carry out breeding tests with females of the slower breeding species; half the cow's breeding life might be over before one could get presumptive evidence of her germinal constitution. Genotypic selection would therefore be confined to the bull, and the procedure would be to mate him with, say, ten or a dozen red or white or red-roan cows. If he were a homozygous black, all his calves would be black or blue-grey. If he left any red or red-roan calves one could definitely conclude that he was a black × red heterozygote, and therefore he would be discarded.

A similar procedure may be adopted with regard to any other character or group of characters. If the trial matings be made with carefully chosen females, and if the progeny be sufficiently numerous, a very complete picture can be obtained of the germinal constitution of the sire. Thus the best test of the capabilities of a dairy bull is the average production of a number of his daughters, compared with the

average production of their dams. With meat-producing animals, too, the most satisfactory basis on which to judge a sire would be the economy of production and the quality of the meat produced by a number of his progeny. Such experimental tests are actually made with pigs by the Danish and Swedish Pig-testing Stations; groups of four progeny of each sire are reared, fed, and finally converted into bacon under carefully controlled conditions, and the results are used in the final selection of stud animals from among the sires. Such results are very valuable, for they constitute a test of the true commercial value of the animal under ordinary farm conditions.

Fixing Type.

When there has been obtained an animal with something approaching the desired set of hereditary characters, the problem arises of maintaining or fixing this combination in a herd or flock or strain. While it is true that no breeder has yet succeeded in producing a perfect animal, or even one possessing a full complement of all the best characters of its breed, still success in the breeding of really fine individuals is comparatively common. It is definitely more difficult to build up a herd in which the good qualities are transmitted in any complete or regular fashion. Take milk-production for example. Individual yields of 2000, 3000 gallons, and even more, have been obtained. The best herds on the other hand produce averages of between 800 and 1000, and this under a system of continuous culling—that is to say, the average is not that of the females bred, but the average after a considerable proportion of the poorest producers have been discarded. In many countries the average production is 400 gallons or less. Admitting that milk-production is influenced by many circumstances other than heredity, one cannot avoid the conclusion that it is extremely difficult to get a fixed and true-breeding strain of heavy producers. It is obvious, too, that this end is of far greater importance than that of securing a few high individual records.

Inbreeding.

It has been known since the time of Bakewell that inbreeding, the mating together of closely related animals, is a valuable aid in the fixing of type, *i.e.*, in the production of strains in which the same characteristics are regularly reproduced. The discovery by Bakewell of the value of inbreeding seems to have been due to the accident of circumstances. He had new and original notions as to what constituted merit in a sheep or a steer, and after he had formed his flock and herd, and had gone some way with their improvement, he naturally found it increasingly difficult to obtain, from outside, sires that he considered good enough to introduce. He therefore turned to home-bred sires, and gradually, as his blood lines became intermingled, he resorted to more and more intensive inbreeding. On the whole, his results were exceedingly good.

This effect of inbreeding, the fixing of type, is readily explicable on the Mendelian hypothesis. If we take a group of plants that are heterozygous for a particular character—say a hundred pink-flowered *Mirabilis*—and cause them to become self-fertilised, 50 per cent. of the progeny will be heterozygous, *i.e.* pink, while the other half will show either of the homozygous conditions, white or red. If this generation is selfed again the whites and reds breed true, while the pinks produce 50 per cent. of the hybrid (pink) and 50 per cent. of the homozygous (white and red) forms. Thus, if the various forms are allowed to multiply in the same ratio, the proportion of heterozygous, or non-pure-breeding types, decreases from generation to generation in the series $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$, $\frac{1}{16}$, and so on. After ten generations of self-fertilisation the pure types would constitute 99·9 per cent. of the population. Similarly, if we start with a multiple hybrid—*i.e.*, with a plant having a large number of characters in the heterozygous condition—the *average* number of heterozygous characters will be halved each time that self-fertilisation occurs. If, for example,

we cross two varieties of wheat that differ in sixteen Mendelian characters, and allow the progeny to self-fertilise for a dozen generations, it may be calculated that over 99 per cent. of the progeny will have automatically reached the homozygous or true-breeding condition. This is in accordance with the discovery, made independently, that in species that are regularly self-fertilised, the vast majority of individuals do actually breed true.

Self-fertilisation is, of course, the most intense form of inbreeding that it is possible to conceive, but other forms differ from it not in kind but only in degree. Whenever inbreeding is practised, characters tend to separate out in the homozygous condition, and the closer the degree of relationship, the more rapid will tend to be the process of segregation into pure-breeding strains. Continuous out-crossing, on the other hand, tends to keep a maximum of characters in the heterozygous condition, with a correspondingly wide range of possible combinations and a high degree of variability.

It must be pointed out that absolute purity of type, in the Mendelian sense, has probably never been reached with farm animals. In order to isolate "pure lines" from an ordinary mixed stock we should have to breed very closely for a considerable number of generations. In the case of full-brother-and-sister matings it might take some twenty generations. Nothing approaching this amount of inbreeding has ever been attempted in practice, and so far we can only speak of strains of farm animals as relatively pure. Even in the most carefully selected and most closely bred families there must remain a considerable number of heterozygous characters. That this should be so, in spite of the obvious advantages of pure-breeding types, is accounted for by another phenomenon connected with inbreeding.

Very generally, when attempts have been made to inbreed through several generations, the breeder has found that his stock deteriorated in some respect—showed a lack of size, or vigour, or both; susceptibility to disease; lessened fertility, or perhaps complete sterility. A good many systematic inbreeding experiments have been carried out with small

animals, such as rats and guinea-pigs, and very often similar results have been obtained. The first explanation that was proposed to meet the case was that physiological vigour, fertility, and the like depended in part at least on the heterozygous condition of certain characters. A hybrid, it was supposed, was vigorous because of its hybridity. A homozygous strain, on the other hand, was lacking in vigour, because it was homozygous. Fertility, size, and vigour were thus regarded as belonging to that type of character which is due to heredity and is yet incapable of being fixed, like, for example, the pink colour in *Mirabilis* or the blue-grey colour in cattle. If this explanation be accepted, it is obvious that the practical breeder must be forced into a perpetual compromise between inbreeding and out-crossing—inbreeding sufficiently to ensure some degree of regularity of transmission, but reverting to a broader basis as soon as ill effects begin to appear. But, recently, evidence has accumulated which seems to show that this explanation will not hold, and another and more probable one has been proposed to account for the facts.

In the first place it is to be noted that inbreeding is not always associated with a decline in vigour. It is so very generally when it is applied for a few generations to the higher animals or to such plants as are normally cross fertilised. But many plants, such as oats, beans, sweet peas, etc., are almost regularly self-fertilised and yet remain perfectly vigorous and healthy. Moreover, in certain recent experiments with rats and guinea-pigs, it has been demonstrated that very highly inbred strains may remain fully normal. Thus Miss King, in America, started with a strain of white rats and inbred them by full-brother-and-sister matings for twenty-five generations. The average size of litter declined from 6·8 in the first generation to 5·0 in the third, but between the twentieth and twenty-fifth generation the mean litter fluctuated between the 7·2 and 7·7. Similarly, measurements of size, rate of growth, mortality, etc., showed that the strain after twenty-five generations of inbreeding was fully as healthy as the original. A similar

experiment with guinea-pigs has been carried on by the United States Department of Agriculture since 1906. It was started with thirty-three pairs of guinea-pigs, and a family was bred from each pair by successive brother-and-sister matings. Fully half the families, indeed, have died out, owing to their low birth-rate and high mortality. Several more families show a very distinct loss of vigour and fertility, so that they are kept going with some difficulty. Yet there remain others that compare very favourably in every way with the parent stock. In many families there was a sort of critical period in which the ill effects of inbreeding were very marked. Some failed to survive this period. Others that did, and settled down to a true-breeding condition, showed sometimes a loss and sometimes an actual gain in vigour as compared with the parent stock. It is obvious, therefore, that inbreeding does not necessarily, or as such, cause a loss of vigour. Some homozygous strains are unsatisfactory, but others are fully normal, and therefore we cannot conclude that there is any necessary or inevitable weakness attached to the true-breeding type as such. An explanation must therefore be sought for in the nature of the hereditary characters themselves.

That the results of inbreeding, when they are considered in the mass, are generally bad, is explained as follows. Unfavourable genes, such, for example, as those producing diminished growth, or lessened fertility, or perhaps even sterility or death, arise by mutation from time to time. The factor producing yellow colour in mice is an example, and a great number have been observed to occur in *Drosophila*. If the unfavourable factor is dominant, it is obvious that it will either be automatically eliminated or will be quickly and easily got rid of by selection. Again, in self-fertilised plants, the unfavourable character will appear in the homozygous condition almost as soon as it occurs and, whether it be dominant or not, will tend to be eliminated very soon. But, if an unfavourable mutant character happens to be recessive to the normal condition, and if it occurs in a cross-fertilised species, it may be carried

on for many generations without its presence being suspected, like the red colour in the Aberdeen Angus. Most strains of animals, it seems, carry and transmit such a heritage of hidden defects. There may be a large number of different unfavourable recessives in a breed, and so long as no one is very common, and so long as random mating is permitted, the number of pure recessives (which alone will show the unfavourable character) will be small. Thus, if in a particular strain one animal in ten carries a certain unfavourable recessive, and mating is random, only one animal in four hundred will show the unfavourable character.[1] Even if we had twenty such factors, distributed in the same proportion, we should still get 95 per cent. of normal progeny and only 5 per cent. of defectives. As soon, however, as we begin to confine matings to related individuals, we greatly increase the probability of the two parents having the same recessive defects, and hence we get a greatly increased proportion of the defective pure recessives. Thus, in the foregoing illustration the average number of unfavourable recessives carried by a particular animal will be two, *i.e.* one tenth of twenty. If, through inbreeding, we mate together two animals that carry the same two recessives, we should get 25 per cent. showing the one unfavourable character, and 25 per cent. of the remainder showing the other, *i.e.* seven-sixteenths of the progeny would show either or both of the unfavourable characters. Even then, though we should be past the worst, we should still be left with a large proportion of animals with one or other, or both recessives in the heterozygous condition and therefore we should continue to get a proportion of defectives for several generations. In actual practice the question would be complicated, in all probability, by linkage relationship,

[1] Matings would occur as follows :—

Homozygote × homozyote .	. $\frac{9}{10} \times \frac{9}{10} = \frac{81}{100}$	= 81 per cent.
Homozygote × heterozyote .	$2(\frac{1}{10} \times \frac{9}{10}) = \frac{18}{100}$	= 18 „
Heterozyote × heterozyote .	. $\frac{1}{10} \times \frac{1}{10} = \frac{1}{100}$	= 1 „

Only the last mating will give the pure recessive, and then only in one-fourth of the progeny.

which might be expected to render the process of breeding out the bad characters considerably more tedious.

Inbreeding then does not produce new hereditary defects but only brings to light old ones. It does not lead, as was formerly supposed, to indefinite progressive deterioration. It merely results in Mendelian segregation, and deterioration ceases as soon as segregation is complete. The separate pure lines into which the inbred strain resolves itself are good or bad according to the particular sets of genes that they respectively receive. If, as frequently happens, a majority of the inbred animals are inferior, this only goes to show that the number of unfavourable recessives in the original strain was large. Obviously then intensive inbreeding should be carried out only with carefully chosen material, and even then it must be accompanied by rigorous selection. What is called "line breeding" is merely a non-intensive form of inbreeding and produces in the end the same result, particularly where it is accompanied by careful genotypic selection. The rate of progress towards the desired end of fixity of type will, however, be slower in proportion as the degree of consanguinity is less.

Grading and Crossing.

Where a breeder starts, as is often inevitable, with a collection of females of average or inferior quality he should normally endeavour to grade up his flock or herd by the continued use of pedigree sires. Obviously before he begins operations he should convince himself that one or other of the pure breeds will provide the type of animal he desires, and having once decided on a particular breed he should not lightly discard it for another. Certain of the Breed Societies encourage such grading by admitting to their registers "grade" animals with a certain proportion of non-pedigree ancestry. So long as the breeder is in the grading up stage —*i.e.* so long as he is able to obtain from outside sources sires that are reasonably certain to improve the standard of merit in his herd—there is no particular advantage to be gained by close inbreeding ; on the other hand, if he happens to secure

a particularly good and impressive sire he should not hesitate to concentrate his "blood," and the experiment of mating him to his own progeny will often be worth trying. A breeder who is grading up may study pedigrees with just as much advantage as the pedigree breeder himself, for if he is content to buy any registered sire on his appearance alone he may get an animal of mixed or inferior ancestry that may bring him serious loss.

Cross Breeding, so long as it is carried out systematically, has, for the production of "commercial" animals, certain definite advantages over pure breeding. Cross bred animals commonly show the phenomenon of *heterosis* or hybrid vigour —that is to say they grow more rapidly, are more prolific and more resistant to disease than pure breds. Theoretically of course it is possible to collect a complete set of desirable dominant factors in a single homozygous strain, but many generations must elapse before this can be accomplished with farm animals. Meantime such valuable dominants as have been fixed in two breeds can be combined by crossing. Heterosis is at its maximum in the first cross; hence cross breeding should not be carried beyond this stage or, at the most, beyond that of mating a first-cross female with a pure bred male. In the latter case the disadvantage of irregularity in the second cross generation may be outbalanced by the advantages of hardiness and prolificness in the cross-bred dams.

In practice cross breeding offers the greatest advantages in highly prolific species like pigs and poultry because in these cases a relatively small proportion of pure matings will suffice to produce the necessary supply of selected pure bred females. In the less prolific species a large proportion of the females born must be kept for breeding, and widespread crossing involves the retention either of cross bred females or of inferior pure breds. In the case of dairy cattle crossing is very liable to degenerate into mongrelising, because the cow must breed in order that she may milk. Normally grading is the better system to pursue in dairy herds.

It is a common misconception that inferior pure bred sires

are good enough for crossing. It is true of course that there is a limit to the sum of money that can be profitably invested in a crossing sire, and it is also true that animals which are faulty to the eye of the pedigree breeder may be excellent from the point of view of the commercial breeder. But it is only by careful selection of his sires, and by careful study of his results that the cross-breeding farmer can hope to repeat his successes and avoid recurrence of his failures.

CHAPTER II

THE PRINCIPLES OF NUTRITION

The Constituents of Feeding Stuffs.—Since most feeding stuffs contain a great variety of chemical substances, possessing fundamentally different functions in the animal economy, it is necessary to begin any discussion of the principles of nutrition with some kind of classification of the constituents of common foods. This classification must necessarily be somewhat general, because not only are the compounds very numerous, but the chemical constitution of many is but imperfectly known.

The first step in the analysis of a feeding stuff is to separate the dry matter from the water. This is accomplished by heating the material at the boiling-point of water until a constant weight is obtained, the loss representing the moisture. The importance to all animals of an adequate water supply is too well known to require more than mention; but in practice water is without economic value. Hence, other things being equal, feeding stuffs are valued commercially according to their dry-matter content. This varies within wide limits; most concentrates, hay, straw, etc., in good air-dry condition contain from 85 to 90 per cent. of dry matter; in most green forages the dry-matter content is between 20 and 30 per cent., while in turnips and swedes the percentage may fall below 10. A high water-content obviously adds to the cost of transporting and handling a feeding stuff. On the other hand, succulent materials, such as green forage, roots, and silage have a certain value in improving the palatableness of the ration.

The next step is to separate the dry matter into a so-called "organic" portion on the one hand and mineral matter

or ash on the other. In the ordinary routine of analysis the dry material is incinerated at a dull-red heat and the quantity of unburnt residue is stated as ash. The substances composing the ash include, for example, sulphates, chlorides, phosphates, and carbonates of magnesium, calcium, potassium sodium and iron, and also silica. Some of these substances are doubtless present in the feeding stuff in the form of inorganic salts, but it is well known that others, such as sulphur and phosphorus, exist in the plant partly in organic combination, and form inorganic compounds only during the process of incineration. To some extent, therefore, this division is unsatisfactory. The amount of ash in the dry matter of ordinary feeding stuffs ranges from under 2 to over 5 per cent. All animals require considerable quantities of minerals, notably of lime, phosphates, and common salt, while quite small amounts of other elements, such as iron and iodine, are no less essential to health. Many ordinary rations provide ample supplies of ash to meet all requirements, but in certain cases the mineral ingredients of the ration demand consideration. Thus while a fattening animal that is already full grown, or nearly so, is very unlikely, under ordinary farm conditions, to suffer from mineral deficiency, young animals in rapid growth and deep milking cows may frequently obtain less than they require. Again stock that is living under natural conditions—for example on normal good pasture—is almost certain to get adequate mineral food; but if the soil is seriously deficient in lime or phosphates deficiency diseases may appear in the grazing animals. Further, it should be borne in mind that most of the ordinary concentrates such as cereals and cereal offals, and the commoner cakes and meals, contain very inadequate amounts of calcium; hence all animals that receive a large proportion of their food in such forms, as sty fed pigs and winter milking cows, may suffer from a deficiency of lime. In many cases ill effects on the animal are due rather to a lack of balance between the various minerals than to actual shortage of specific ingredients. In particular phosphoric acid may be present in too large quantities in relation to lime, and

potash in relation to soda. The first defect may be remedied by the addition of chalk to the ration, the latter by providing a salt lick.

Returning to the organic constituents, the first broad division is made between those compounds that contain nitrogen and those others that are composed entirely of carbon, hydrogen, and oxygen. The nitrogenous constituents include a vast number of different compounds, some relatively simple in constitution, others of very great complexity. The most important group is that of the proteins, of which the casein of milk, white of egg, and the gluten of wheat are well-known examples. These are substances of very complex and imperfectly known constitution containing generally from 15 to 17 per cent. of nitrogen. On hydrolysis they break down into great series of simpler substances, chiefly amino-acids, among which leucine, proline, and glutamic acid generally occur in quantity.

The remaining nitrogenous substances, generally termed simply non-proteins or sometimes amides, include amides and amino-acids as well as nitrogenous glucosides, alkaloids, lecithins, etc. Many of them are soluble crystalline substances of known constitution, and a large number are to be regarded as the "building stones" out of which the more complex protein molecule is made. They occur in largest quantity in actively-growing vegetable tissues, in which proteins are either being built up or broken down Thus in ripe seeds they constitute less than one-tenth of the total nitrogenous substance, whereas in green forage they may amount to nearly one-half, and in mangels and potatoes to as much as nine-tenths. The amount of crude protein (*i.e.* of total nitrogenous substances) in feeding stuffs varies within very wide limits. Cereal straws contain only a fraction of 1 per cent., while some of the oil cakes have 30 or 40 per cent. In general the immature plant contains relatively more protein and less oil, starch, etc., than the mature.

It is important to note that the various proteins are differently constituted—are made up with varying pro-

portions of the several "amides" which may be considered as the "building stones" of the protein molecule. The food protein is broken down by the animal into its constituent "building stones," and the latter are reassembled in new proportions to form the various proteins of the body. Any surplus of a particular building stone is broken down for the sake of the energy it contains, and its nitrogen is excreted. It follows that different mixtures of food protein may differ in efficiency, a larger or smaller quantity being required to produce a given amount of body protein. In general animal proteins, such as those present in fish meal, meat meal, and blood meal, have a higher efficiency than vegetable proteins. Further, a mixture of proteins derived from several distinct species or families of plants is usually better balanced and more efficient than a mixture derived from a single species. Certain individual plant proteins are useless, when fed by themselves, because they do not contain one or other of the building stones of the body proteins. It follows too that while a single amide, fed alone, must be quite useless to the animal, the same substance fed in conjunction with other amides and proteins may be fully utilised.

Much remains to be done before protein can be rationed upon a strictly scientific basis. At present the conventional method of calculating the protein value of a food-stuff is to add together its content of digestible true protein and half the amount of the digestible non-proteid nitrogenous substances, the sum being expressed as "protein equivalent." The requirements of the animal, expressed in terms of protein equivalent, are calculated with a certain margin of safety, and it is assumed that the protein will be derived from a reasonable number of separate sources.

The chief non-nitrogenous constituents of feeding stuffs are carbohydrates and fats. The ordinary fats and oils are compounds (esters) of the fatty acids, such as stearic, palmitic and oleic, with glycerol; three fatty acid radicles, which may be the same or different, being united with the glycerol base. On hydrolysis or "saponification" the fats are split up into

fatty acids and glycerol. In the ordinary process of feeding stuff analysis the dry and finely ground material is subjected to prolonged treatment with hot ether, and the quantity of substance removed in solution is stated as "ether extract" or "crude fat." When the feeding stuff in question is, say, an oilseed, the ether extract is very largely actual fat and has a feeding value very nearly as great as that of a chemically pure sample. On the other hand, in straw, hay, green forage, silage, and the like, the ether extract contains a considerable quantity of other compounds—resins, waxes, organic acids, chlorophyll, etc.—which have a considerably lower feeding value than true fats.

The carbohydrates may be divided into several groups, of somewhat different values in nutrition.

1. Simple Sugars or *Monosaccharoses*, including hexoses, such as grape and fruit sugars, with the general formula $C_6H_{12}O_6$, and pentoses, with the general formula $C_5H_{10}O_5$.

2. *Disaccharoses*, such as cane, milk, and malt sugars with the general formula $C_{12}H_{22}O_{11}$.

The sugars are crystalline substances generally freely soluble in water and diffusible through membranes.

3. *Polysaccharides*, of much higher molecular weights, generally non-crystalline and not diffusible. They include the hexosans, such as starch, dextrin, cellulose, etc., with the general formula $(C_6H_{10}O_5)_n$ and yielding hexoses on hydrolysis, and the pentosans, such as the pectins of fruits, turnips, and mangels, with the general formula $(C_5H_8O_4)_n$, and yielding pentoses on hydrolysis. Many of the polysaccharides, such as starch and dextrin, are readily digestible and, owing to their somewhat higher carbon content, have a rather higher feeding value than the sugars. Others, such as the celluloses, lignins, and cutins of "crude fibre," are only partially digested and are consequently of much less nutritive value.

In the chemical analysis of feeding stuffs the water, ash, and "crude fat" are determined directly, and the total nitrogenous matter is estimated from the content of nitrogen. It is assumed that the difference between the sum of these

constituents and the total weight represents carbohydrates. A distinction is made, however, between those carbohydrates (such as sugars) that are soluble in water, together with those (such as starch) that are easily hydrolysed into soluble substances, and those others (such as cellulose and lignin) that are very difficult of hydrolysis. The material is treated by boiling for stated periods first with dilute acid and then with dilute alkali, and the organic matter not dissolved is stated as "crude fibre." The remainder that is still unaccounted for, *i.e.* the non-fatty, non-nitrogenous, dry organic matter, free from crude fibre, is stated as "carbohydrates" or "nitrogen free extract." The process of extraction by acid and alkali is not strictly comparable to that of digestion, yet it serves to distinguish between two groups of carbohydrates that possess widely different values to the animal. In the case of ruminants, it is true, a considerable proportion of the crude fibre is digested with the assistance of bacteria, which by fermentation break down the fibre into methane, hydrogen, and organic acids. Only the last of these substances is assimilated, the gaseous products representing so much loss. The fermentation process of course also produces heat, but it is only under conditions of extreme cold and scant feeding that this heat is an asset of any value. Thus even in herbivora the "digestible crude fibre" is only very partially utilised, while in animals like the pig the fermentations are much less extensive and the fibre can scarcely be said to be digested at all.

Some twenty years ago the discovery was made that when young animals are fed upon a balanced ration of chemically pure nutrients — carbohydrates, fats, proteins, minerals, and water—they cease after a certain period to make growth. The addition to the diet of a small quantity of milk was sufficient to restore normal growth almost immediately. This effect has been traced to a substance of unknown chemical composition which is present in milk in very small proportions and which has been called vitamin A. Since that time four other abnormal conditions

or deficiency diseases have been traced to the absence of accessory factors or vitamins in the food; therefore five separate vitamins are now recognised, and it is probable that others remain to be discovered.

Vitamin A (fat soluble) is necessary for normal growth. It is present in relatively large amount in crude cod-liver oil and in smaller though still ample quantities in the green leafy parts of plants. The substance is destroyed when the material containing it is completely dried in the presence of air. It is thus absent from bleached hay but may be present in well-secured green hay.

Vitamin B (water soluble) is especially abundant in yeast; it is usually absent from the inner portions of seeds, but is present in relatively large amounts in their husks (bran, rice meal, etc.) and in many other plant products. Its absence is the cause of beri-beri or polyneuritis in man, a disease that occurs when the diet consists almost exclusively of polished rice. Beri-beri can be cured in a very short time, even when the patient is at the point of death, by administering a watery extract of the rice husk.

Vitamin C (water soluble) is present in greater or less amount in most fresh fruit juices, but is absent from dried, salted, and sterilised foods. Its absence is the cause of scurvy.

Vitamin D (fat soluble) is in some way connected with mineral metabolism, and its absence causes rickets.

Vitamin E (fat soluble) is present in the leaves and seeds of many species of plants, and unlike vitamin A is present in vegetable oils. It is specially abundant in wheat germ. A supply seems to be essential to fertility. Rats at least become sterile when the substance is withheld, and fertility is restored when it is again fed.

These facts are of great interest to the physiologist, but it does not seem that they greatly concern the farmer. Most ordinary farm rations contain supplies of vitamins that are in excess of the animals' requirements, and this excess can be stored up in the tissues in sufficient amounts to tide over any periods of vitamin shortage that are likely to occur.

When, however, animals are fed indoors for long periods on rations of a highly artificial type, small quantities of fresh green food (vetches, lucerne, green grass, cabbage kale, etc.) may be given with advantage. Such materials, besides adding to the vitamin supply, will generally improve the mineral balance of the food. Failing a supply of green stuff, occasional doses of crude cod-liver oil may be justified in the case of young animals.

Recent work has shown that the metabolism of the animal may be affected by its exposure to light, and in particular to ultra-violet rays. Further, the nutritive value of certain foods can be altered by exposure to ultra-violet light. The explanation is that vitamin D can be manufactured in the skin under the influence of these rays, and that the substance ergosterol, which is present in many foods, becomes, in fact, vitamin D when it is subjected to the influence of such light. Hence animals that are exposed to direct sunlight are not liable to rickets, but house-fed animals readily suffer if their rations are deficient in minerals or vitamins.

Food Requirements.—The food requirements of the animal are of two kinds. In the first place, it requires a supply of certain substances for the repair of its tissues, the production of secretions, and for the maintenance of normal reaction and osmotic pressure in its body fluids; in the case of the growing animal there is obviously an additional requirement for the building up of new tissues. Secondly, a supply of energy is essential to the continuance of the various processes and reactions that constitute life. The animal has been compared to an internal combustion engine or to a motor car. Just as, in the running of a car, certain substances such as rubber and metals are used up and require to be replaced, so in the running of the animal machine, ash and protein are subjected to wastage and must be supplied afresh in the food. The vitamins have been compared to the lubricants of the mechanism of the car—in both cases the consumption is small and supplies may be given at considerable intervals of time, but in both cases their omission leads to ultimate disaster. Finally, the animal must be supplied with energy

in the form of food just as the car must have energy in the form of fuel. In both cases the design permits of the carrying of a certain reserve of energy supplying substance. The analogy is of course incomplete in certain particulars, notably in that the animal has a considerable energy requirement when at rest.

Since energy may exist in many forms—as heat, light, electric energy, chemical energy, and so forth—it may be measured in units of various kinds; in nutrition the customary unit is the Calorie, the quantity of heat energy required to raise the temperature of a kilogram of water from 0° to 1° Centigrade. A more convenient unit is the therm, equal to 1000 Calories.

The total energy of a nutrient substance or a feeding stuff is the quantity of heat produced on burning a given weight, say a pound or kilogram, assuming that the end products of combustion are CO_2,H_2O, N_2,SO_3, etc. In so far as a nutrient is completely digested and absorbed by the animal, and is oxidised to the extent just indicated, it yields to the animal the same quantity of gross energy as it would produce in burning. Thus, for example, a pound of cane sugar produces 1·8 therms on burning, a pound of fat gives 4·3 therms, or nearly two-and-a-half times as much, the difference being accounted for by the higher carbon and lower oxygen content of the fat. If we regard these two substances as completely digestible and as being broken down to CO_2 and water, then the animal would obtain 1·8 therms of metabolisable energy from a pound of cane sugar and 4·3 therms from a pound of fat.

It will be obvious, however, that the quantity of heat produced by a feeding stuff in burning is not necessarily a measure of its energy value to the animal. Coal, for example, has a very high calorific value, but as a feeding stuff it would yield no energy whatever. Only such constituents of a feeding stuff as are digested can possibly be of value. Moreover, the breaking down of certain nutrients stops short before oxidation is complete. The nitrogen of the proteins for example is excreted not as free nitrogen but in the form

of urea, hippuric acid, etc., substances that still contain a measurable quantity of energy. Thus if we are to arrive at the amount of energy abstracted by an animal from its food, we must deduct from the total energy value of the latter the remaining energy value of the excreta—solid, liquid, and gaseous. The difference is termed the metabolisable energy. Armsby gives the following example of such a calculation for a steer:—

Energy of Food—		
6,988 grams Timothy hay		27,727 Cal.
400 grams Linseed meal		1,811 „
Total		29,538 Cal.
Energy of Excreta—		
16,619 grams fæces	14,243 Cal.	
4,357 grams urine	1,210 „	
142 grams methane	1,896 „	
Total		17,349 „
Difference, metabolisable energy		12,189 Cal.

The quantity of metabolisable energy yielded by a feeding stuff is obviously the maximum that can conceivably be of value to the animal. But the whole of the metabolisable energy of the food is not available for actual use. The very act of ingesting food involves the animal in an expenditure of energy, *e.g.* in the labour of mastication, in glandular activity, and peristalsis. The bacterial fermentations that occur in the alimentary canal of ruminants also result in a considerable dissipation of energy. It is true that, since no external work is being done, the final form in which this energy escapes is heat, and in so far as this heat is required for the maintenance of the body temperature, it serves a useful purpose. For each particular animal, receiving a particular ration, there is what is called a critical temperature. This is the air temperature at which the vital processes generate just sufficient heat to maintain the normal body temperature. For the fasting pig, for example, it is about 78° F.; that is to say, energy is saved by keeping the animal at a temperature of 78° as compared with any

lower temperature, but no further saving is effected by raising the temperature above this level. In other words, the animal would starve to death sooner at a temperature of 60° than at 78° but would live just as long at 78° as at 90°.[1] The critical temperature is lowered very much when the animal receives food, owing to the consequent increase in the amount of internal work. Thus for a pig on normal rations the critical temperature is about 40° F., or 8° above freezing point. It may thus happen that pigs, during spells of cold weather, have to expend energy directly in keeping themselves warm. In this respect the horse resembles the pig, though the actual critical temperature is not known. It probably varies widely according to the condition of the coat. The case of the ruminants is different. Under normal conditions of feeding, with a reasonable proportion of rough forage, the amount of heat that is produced is so great as to make the critical temperature very low. At ordinary temperatures there is produced a large surplus of heat, and it is therefore a mistake to suppose that to keep up the temperature of the animal's surroundings is always to effect a saving of food. With cattle, and still more with sheep, the critical temperature will ordinarily be so low that the air temperature may vary within wide limits without making the slightest difference in the energy requirement. The temperature of byres and the like should therefore be adjusted on grounds of general health.

If we add to the food of an animal that is already above its critical temperature, we increase its output of heat, and this additional expenditure must be deducted from the metabolisable energy before we can arrive at the net gain of energy to the animal. This is well shown by the results of a calorimeter experiment by Armsby and Fries. A steer was fed on a sub-maintenance ration of about 6 lb. of

[1] It is of course true that other factors than air temperature influence the matter. Wind, atmospheric moisture, wet bedding, etc., would cause an extra expenditure of heat as compared with still air and dry conditions. The whole "thermal environment" must be taken into account.

timothy hay, containing about $5\frac{3}{4}$ therms of metabolisable energy. The heat emitted by the animal was about 8 therms, so that there was a loss of energy amounting to $2\frac{1}{4}$ therms per day, which fell to be met by a breaking down of body fat or other tissues. The hay was then increased to something over 10 lb. per day, which gave the animal a supply of metabolisable energy of $9\frac{1}{2}$ therms, or $1\frac{1}{2}$ more than the previous expenditure. If, therefore, the whole of the metabolisable energy of the added food had been available to the animal, it would have been able to store energy (in the form of fat, etc.) at the rate of $1\frac{1}{2}$ therms per day. Under the new conditions, however, the heat emitted rose to $9\frac{3}{4}$ therms, so that there was still a loss at the rate of one-quarter therm per day. The conclusion to be drawn is that whereas each pound of hay supplied 935 Calories, or nearly 1 therm of metabolisable energy, 433 Cal. of this energy was expended in the work of digestion, or was lost by reason of fermentations in the alimentary canal, and only the balance of 502 Cal. was actual gain to the animal. The last figure, 502 Cal. per pound, is termed the *net energy value* of the feeding stuff. The point is that there is a debit as well as a credit side to the energy account of any food; the total energy value—the heat yielded by the material on burning—is the gross income. If we deduct the energy value of the excreta, the balance is metabolisable energy. And if, from this again, we deduct the amount of energy expended in the work of digestion, we arrive at the credit balance, the net energy value.

The proportion of the total energy that is metabolisable and the proportion of metabolisable energy that remains as net energy vary with the nature of the feeding stuff and also with the type of animal consuming it. Thus maize meal and wheat straw have roughly the same total energy values of about $1\frac{3}{4}$ therms per pound. In experiments with ruminants it has been found that about 85 per cent. of the total energy of maize meal is metabolisable and about 50 per cent. is net. Of the total energy of wheat straw 40 per cent. is metabolisable and only 7 per cent. net. Maize meal there-

fore supplies seven times as much net energy, weight for weight, as wheat straw. Again a pound of digested starch supplies to the ruminant 1·07 therms of net energy, whereas the pig obtains about 1·50 therms from the same amount. The pig is therefore much more efficient than the steer in the utilisation of the energy of materials like starch, a difference which depends on the different nature of the digestive processes. The process in ruminants, involving as it does rather prolonged bacterial fermentations, is well adapted to make the most of coarse fibrous materials, but is very wasteful as regards concentrated and easily digestible foods.

Since net energy is the difference between the income from a feeding stuff and the expenditure in the work of its digestion, it follows that where the expenditure exceeds the income the net energy value must be a negative quantity. Such negative values have in fact been obtained. Saw-dust and peat, for example, and even in the case of the horse wheat straw, cost more energy in digestion than they yield in metabolisable form, and hence are not only useless, but worse than useless as foods.

In this country the customary unit of net energy is neither the Calorie nor the therm, but the quantity that is obtained by the animal from each unit weight of starch digested by it. This system of so-called *starch equivalents* was devised by Kellner. The starch equivalent of a feeding stuff may be defined as the number of pounds of pure starch that the animal would require to digest in order to supply the same quantity of net energy as 100 lb. of the feeding stuff in question. Thus, if we say that the starch equivalent of linseed cake is 74, or that that of undecorticated cotton cake is 40, we mean that, as sources of energy, 100 lb. linseed cake are equal to 74 lb., and that 100 lb. undecorticated cotton cake are equal to 40 lb. of digested starch.

The starch equivalent of a feeding stuff may be calculated from its content of *digestible* nutrients as follows:—

(1) The metabolisable energy is estimated on the assumptions that (1) each pound of protein supplies as much

energy as 0·94 lb. of starch; (2) that each pound of carbohydrates or crude fibre yields the same quantity of energy as a pound of starch; and (3) that each pound of ether extract yields as much energy as 2·41, or 2·12 or 1·91 lb. starch according to its origin. The highest factor (2·41) applies to the ether extract of oil seeds, which, as already pointed out, is practically pure oil; the second factor (2·12) applies to seeds other than oil-seeds—*e.g.* cereals; and the third (1·91) applies to the ether extract of hay, straw, green forage, etc., which contains a considerable proportion of substances that have a lower energy value than true fats or oils.

(2) With most feeding stuffs a certain deduction must be made from the total so obtained because they are less easily digestible than starch, *i.e.*, the "work of digestion" is relatively greater. In other words, the net energy yielded by them bears a lower proportion to their metabolisable energy than is the case with starch. This deduction is made in the case of concentrates by multiplying the total, as obtained by the method described above, by a "percentage value" figure. Thus the "value" of the nutrients in linseed cake, as determined by actual experiment is 97 per cent., which is to say that the net energy is 3 per cent. less, in proportion to the metabolisable energy, than in the case of starch. The respective "percentage values" of the various feeding stuffs have been allowed for in calculating the starch equivalent figures given in the table of feeding stuffs in the Appendix (Table III.). The following calculation of the starch equivalent of oats (100 lb.) will serve to make the method clear.

Starch Equivalent of Oats.

Digestible protein, 7·2 per cent. × 0·94	= 6·77
„ carbohydrates and crude fibre, 47·4 × 1·00 .	= 47·40
„ ether extract, 4·0 × 2·12	= 8·48
Therefore total metabolisable energy in terms of starch .	62·65
"Percentage value" . = 95	
Therefore starch equivalent = $62·65 \times \frac{95}{100} = 59·5$	

The foregoing method of using a "percentage value" was found by Kellner to give unsatisfactory results when applied to hay, straw, and other coarse fodders. This is because the composition of a material like oat-straw or meadow hay varies within such wide limits that no single value factor could apply, even roughly, to all samples. It was found, however, that the "work of digestion" for such fodders varied in proportion to the nature and amount of the crude fibre present in them. Hence the deduction from the metabolisable energy is in such cases based on the fibre content. For each pound of total fibre, in the case of hays and straws, the deduction is 0·58 lb. With chaff the constant used is 0·29, and with green forage the figure varies from 0·29 to 0·58 according to the percentage content of fibre. The following calculation gives the starch equivalent of Italian rye-grass hay.

Digestible protein, 4·9% × 0·94	= 4·61
,, carbohydrates and crude fibre, 41·5 × 1 . .	= 41·50
,, ether extract, 1·4% × 1·91	= 2·67
Metabolisable energy per 100 lb., in terms of starch .	= 48·78
Deduct total fibre, 22·9% × 0·58	= 13·28
Starch equivalent per 100 lb.	= 35·5

A table showing the average composition, average content of digestible nutrients, and average starch and protein equivalents of most of the materials commonly used as feeding stuffs is given in the Appendix (Table III.).

The system of starch equivalents has been criticised by many writers, and there is no doubt that the basal idea, that of expressing energy in terms of matter, tends to a certain confusion of thought. There is the further point that whereas the system gives a single figure for each feeding stuff, the actual net energy value varies according to the type of animal that consumes it. Not only are different proportions of the nutrients digested by the ox, horse, pig, etc., respectively, but a unit weight of digested starch gives a different net energy value according to the nature of the digestive process and according to whether the net energy is transformed into

body fat, milk, or work. Thus, for example, Armsby gives the net energy value of maize-meal as 85 therms per 100 lb. for the fattening ruminant, 132 therms for the horse, and 120 therms for the pig. This, however, is a point of minor practical importance if it is shown that the *relative* values of different feeding stuffs are approximately the same for different classes of stock, and this is, according to the available information, and with certain reservations, true. In the following table the net energy values of a few typical feeding stuffs, as determined by Armsby, for the horse and the pig are compared with the starch equivalent figures of Kellner, taking the value of maize as the standard in each case.

	Relative Starch Equivalents. Oxen—Kellner. (Maize = 100.)	Relative Net Energy Values —Armsby. (Maize = 100.)	
		Horse.	Pig.
Maize	100	100	100
Barley	88	...	88
Oats	73	71	...
Bran	51	...	62
Potatoes	23	27	20
Linseed meal	88	77	92
Lucerne hay	30	37	...
Wheat straw	13	−15	...

Bearing in mind the possibility of a certain difference in the composition of the samples used for the determinations, the figures show fair agreement. The negative energy value of wheat-straw to the horse, compared with its small, but positive, value according to Kellner's starch equivalent, is a somewhat marked discrepancy. In general Armsby's figures for coarse fodders (hay straw, etc.) are materially higher than those of Kellner.

While admitting that it would be more satisfactory to have separate sets of figures representing the net energy values of each feeding stuff to each different type of animal, we may accept the starch equivalent figures as affording a fairly satisfactory guide in the rationing of energy. In any

case actual determinations of net energy values in the case of the horse and pig have been made for a relatively small number of feeding stuffs so that we have no other complete set of values.

Turning to the actual procedure to be followed in constructing rations for stock (and neglecting the questions of mineral matter and of vitamins which have already been briefly discussed), the requirements of the animal are two—a source of energy and a supply of protein. Moreover, in each case there is a requirement for maintenance and a production requirement. Hence the animal's needs may be placed under four heads:—

(1) Energy for maintenance, including (2) protein for maintenance.

(3) Energy for production (*e.g.* of body fat, growth, milk or work), including (4) protein for production.

(1) A good many determinations have been made of the energy required for maintenance. It varies with the type of animal and, in animals of the same class, is proportional not to the body weight but to the area of the body surface. Taking the last point first, it will be obvious that the smaller the animal the larger will be its body surface in relation to its body weight. Hence small animals, weight for weight, have a higher maintenance requirement of energy than large ones. The actual relationship is such that the energy requirement varies as the two-thirds power (the square of the cube root) of the live weight. For example, if one animal be three times the weight of another, its body surface, and therefore its maintenance energy requirement, will be $3^{\frac{2}{3}}$ or 2·08 times as great. This relationship seems to obtain for cattle and sheep of all ages, but in the case of pigs only to mature animals, the young having relatively high maintenance requirements. In the case of the horse the measurement of maintenance requirements is beset with so many difficulties that there is no sufficient evidence either for or against the "surface law," but it is generally assumed that the law holds good. A further point about the

maintenance requirement is that it seems to rise to some extent as the animal becomes fat. The figures given below are therefore strictly applicable only to animals in "store" or breeding condition.

While the expenditure of energy when the animal is at rest is subject to but little individual variation, particular animals do in fact require different amounts of net energy to maintain constant body weight; an animal of quiet temperament spends a minimum of energy on movement, whereas an active, restless beast expends a great deal. Thus in a recent trial with Jersey cows it was found that one, a particularly quiet animal, maintained its weight on 3·9 lb. of starch equivalent per 1000 lb. live weight per day, while two others required 5·1 and 5·2 lb. respectively.

For cattle the accepted figure for maintenance is 6 lb. starch equivalent per 1000 lb. live weight per day. This implies, under the "surface law," the following actual requirements for animals of various weights:—

1 cwt. (112 lb.)	1·4 lb. S.E.	6 cwt.	4·5 lb. S.E.	11 cwt.	6·9 lb. S.E.
2 „	2·2 „	7 „	5·0 „	12 „	7·3 „
3 „	2·9 „	8 „	5·5 „	13 „	7·7 „
4 „	3·5 „	9 „	6·0 „	14 „	8·0 „
5 „	4·0 „	10 „	6·5 „	15 „	8·4 „

These figures allow a certain margin for normal movement and apply to all except fat animals.

With regard to sheep the figures given by different authorities are not in close agreement. Kellner's figure is 0·9 lb. starch equivalent per 100 lb. live weight per day, while more recent determinations by Wood have given the much higher value of 1·25 lb.

For pigs Wood's very careful measurements give the following requirements for animals of different weights:—

50 lb. . .	1 lb. S.E.	200 lb. . .	2·5 lb. S.E.
100 „ . .	1·9 „	250 „ . .	2·6 „
150 „ . .	2·2 „	300 „ . .	2·7 „

In the case of the horse the actual net energy requirement when at rest is substantially lower than that of the ox, but

in practice the question of maintenance is complicated by the active temperament of the animal and by its relatively high requirement of metabolisable energy for maintenance of the body temperature. The figure may be put at 4 lb. starch equivalent per 1000 lb. live weight, provided this be supplied in a form such as hay, with a high metabolisable energy in relation to its net energy. On a concentrated diet supplying only 4 lb. of starch equivalent the horse would have to move about to keep itself warm, and would lose weight.

(2) The maintenance requirement of protein is, so far as is known, about the same in all classes of stock and is in simple proportion to the live weight. Only in sheep there is a small additional demand on account of the growth of the wool. It must be borne in mind that different proteins are not of equal value, and that a deficiency in the amount of a particular "building stone," *e.g.* tryptophan, may make necessary the consumption of a larger quantity of protein in order to maintain the balance. All that can be laid down is therefore a rough minimum for animals on an ordinary mixed diet. The figures given by Armsby are 0·05 lb. of digestible true protein daily, per 100 lb. live weight, for oxen, horses, and pigs, and 0·055 lb. for the sheep. Kellner's figures, viz. 0·07 lb. for cattle and 0·10 for sheep, are almost certainly too high. On the whole it may be assumed that the maintenance requirement does not exceed, in horses, cattle and pigs, 0·06 lb. of protein equivalent per 100 lb. live weight per day, and in sheep 0·07 lb.

(3) Energy requirements for production cannot be measured with the same degree of precision. In the case of milk we are dealing with a product of ascertainable composition and consequently we are on safe ground. In regard to growth and fattening we know that the ruminant requires 4 lb. and the pig 2·85 lb. of starch equivalent to produce a pound of body fat. But the live weight increment of an animal is composed of a large number of substances of different energy values—fats, proteins, water, and minerals —and these are stored in different proportions according to

the stage of growth and the manner of feeding. As regards work there is no accurate measure that can be applied in practice. The following figures must be regarded with these reservations in mind :—

Milk production. Butter-fat Content. per cent.	Pounds starch equivalent per gallon (10 lb.).
3·25	$2\frac{1}{4}$
3·75	$2\frac{1}{2}$
4·25	$2\frac{3}{4}$
4·75	3

Growth of ruminants (without fattening) :—

Pounds starch equivalent per lb. live weight increase—

Cattle, at age of—		Sheep, at age of—	
0 to 3 months	$1\frac{1}{4}$	0 to 3 months	1
3 „ 6 „	$1\frac{1}{2}$	3 „ 6 „	$1\frac{3}{4}$
6 „ 12 „	2	6 „ 12 „	$2\frac{1}{4}$
12 „ 24 „	$2\frac{1}{4}$		

Fattening of ruminants (well-developed "stores," with no considerable growth).

Pounds starch equivalent per lb. live weight increase.

Early stages	$2\frac{1}{4}$
Middle stages	3
Last stages	$3\frac{3}{4}$
Average for normal fattening period	3

Combined growth and fattening of baby beeves.

Pounds starch equivalent per lb. live weight increase.

Early stages	$2\frac{1}{4}$
Last stages	$2\frac{3}{4}$

Combined growth and fattening of sheep.

Pounds starch equivalent per lb. live weight increase.

Age, 6 to 12 months	$2\frac{1}{2}$

Combined growth and fattening of pigs.

Pounds starch equivalent per live weight increase.

At age of 2 months	0·5
„ „ 3 „	0·6
„ „ 4 „	0·7
„ „ 5 „	0·9
„ „ 6 „	1·2

At age of 7 months	1·4
„ „ 8 „	1·6
„ „ 12 „	2·0

Work of horses.

Pounds starch equivalent per 1000 lb. live weight per working hour.

Light slow work	¾
Medium slow work	1
Heavy slow work	1¼
Heavy fast work	1½

(4) Protein requirements for production are still more a matter of guess work. In theory fattening and work production do not make any demands on the protein supply, because the product is energy only, but in practice it is found that a certain ratio must be preserved between the digestible protein and non-protein, otherwise complete digestion of the latter is not secured. This ratio, it seems, should be no wider than about one to ten, that is one pound of protein equivalent in each ten pounds of starch equivalent.[1] Where protein is a constituent of the product the requirement may be calculated roughly by taking the amount of protein produced and adding from 60 to 100 per cent. as a "margin of safety." On these bases the figures are somewhat as follows:—

Milk production. Pounds protein equivalent per gallon (10 lb.).

Ordinary breeds	0·6
Channel Island breeds	0·74

Fattening of ruminants (with no considerable growth)

0·35 lb. protein equivalent per lb. live weight increase.

Growth—Ruminants (without fattening).

Pounds protein equivalent per lb. live weight increase:—

Cattle at age of—		Sheep at age of—	
0 to 3 months	0·45		
3 „ 6 „	0·40	3 to 6 months	0·40
6 „ 12 „	0·35	6 „ 12 „	0·35
12 „ 24 „	0·35		

[1] This is not the "albuminoid ratio" as ordinarily understood. The albuminoid ratio is the ratio between the digestible protein and the digestible non-nitrogenous nutrients reckoned as starch.

Combined growth and fattening of pigs.

Pounds protein equivalent per lb. live weight increase.

At age of—			
2 months	0·35	6 months	0·30
3 „	0·35	7 „	0·30
4 „	0·32	8 „	0·28
5 „	0·32	9 „	0·25

Work of horses. 0·10 lb. protein equivalent per 1000 lb. live weight per working hour.

The following examples show the use of these data in the compounding of rations:—

(1) Daily ration for a steer of 1000 lb. live weight at the beginning of fattening, sufficient to produce 2½ lb. live weight increase per day. (Maintenance requirement 6 lb. starch equivalent and 0·6 lb. protein equivalent per 1000 lb. live weight; production requirement 2¼ lb. starch equivalent and 0·35 lb. protein equivalent per pound live weight increase.)

Energy requirement—

Maintenance	6	lb. starch equivalent.
Production	5·6	„ „
Total	11·6	

Protein requirement—

Maintenance	0·6	lb. protein equivalent.
Production	0·87	„ „
Total	1·47	

Energy supply—

80 lb. swedes (starch equivalent = 7 per 100 lb.)	= 5·6	lb. starch equivalent.
14 lb. oat straw (starch equivalent = 17 per 100 lb.)	= 2·4	„ „
5 lb. palm kernel cake (starch equivalent 75 per 100 lb.)	= 3·7	„ „
Total	11·7	

Protein supply—

80 lb. swedes (protein equivalent 0·7 lb. per 100 lb.)	= 0·56	lb. protein equivalent.
14 lb. oat straw (protein equivalent 0·9 lb. per 100 lb.)	= 0·12	„ „
5 lb. palm kernel cake (protein equivalent 17 lb. per 100 lb.)	= 0·85	„ „
Total	1·53	

(2) Ration for Shire gelding of 1400 lb. live weight doing work of average severity for 42 hours per week or 6 hours per day. (Maintenance requirement 4 lb. starch equivalent and 0·6 lb. protein equivalent per 1000 lb. live weight per day; production requirement 1 lb. starch equivalent and 0·1 lb. protein equivalent per 1000 lb. live weight per working hour.)

Energy requirement—

Maintenance, 4 lb. starch equivalent $\times \left(\frac{1400}{1000}\right)^{\frac{2}{3}}$ = 5·0 lb. S. E.

Production, 1 lb. starch equivalent $\times 6 \times \frac{1400}{1000}$ = 8·4 „

Total . . . . . 13·4

Protein requirement—

Maintenance, 0·60 lb. protein equivalent $\times \frac{1400}{1000}$ = 0·84 lb. P. E.

Production, 0·10 lb. protein equivalent $\times 6 \times \frac{1400}{1000}$ = 0·84 „

Total . . . . . 1·68

Energy supply—

16 lb. oats (starch equivalent = 60) . . . . = 9·6 lb. S. E.
4 lb. chaffed oat straw (starch equivalent = 17) . = 0·7 „
10 lb. average meadow hay (starch equivalent = 31) = 3·1 „

Total . . . . . 13·4

Protein supply—

16 lb. oats (protein equivalent = 7·6) . . . = 1·21 lb. P. E.
4 lb. oat straw (protein equivalent = 0·9) . . = 0·04 „
10 lb. meadow hay (protein equivalent = 4·6) . . = 0·46 „

Total . . . . . 1·71

In calculating rations it should be borne in mind that different samples of ordinary feeding stuffs vary rather widely in composition, so that no great degree of exactitude is possible. The progress or condition of the animal is the final test of the sufficiency or otherwise of the food.

Money Values of Feeding Stuffs.

The choice of feeding stuffs, in so far as these have to be purchased, must always in some measure depend on their market prices. Even with home-grown foods it is

often useful to be able to express the nutritive values in terms of money. Many different systems have been proposed for the estimation of comparative money values, the most satisfactory of which is that devised by the Departmental Committee on the Rationing of Dairy Cows.[1] According to this method standard values for the unit (1 per cent. of a ton) of starch equivalent and of protein equivalent are calculated from the current prices, delivered at the farm, of four standard market feeding stuffs, two being starchy and two protein-rich materials. The following example will show the suggested method of calculation :—

	Starch Equivalent.	Protein Equivalent.	Price per ton.
			£ s. d.
Feeding barley	71	6·2	9 10 0
Maize	81	6·8	8 15 0
Carriage (2 tons) . . .	...	...	1 0 0
	152	13	19 5 0 = 385/-
Decorticated ground-nut cake .	73	41	12 0 0
„ cotton cake . .	71	34	11 0 0
Carriage (2 tons) . . .	...	...	1 0 0
	144	75	24 0 0 = 480/-

Let x = Cost of Unit of Starch Equivalent and y = Cost of Unit of Protein Equivalent.

Then $152x + 13y = 385$

and $144x + 75y = 480$

$$(152x \times 144) + (13y \times 144) = 385 \times 144$$

$$(144x \times 152) + (75y \times 152) = 480 \times 152$$

$$(75y \times 152) - (13y \times 144) = (480 \times 152) - (385 \times 144)$$

$$11400y - 1872y = 72960 - 55440$$

$$9528y = 17520$$

$$y = 1{\cdot}84 \text{ shillings} \quad . \quad . \quad . \quad . \quad (1)$$

$$152x + 13y = 385$$

$$152x = 385 - 13y$$

$$= 385 - 23{\cdot}9$$

$$= 361{\cdot}1$$

$$x = 2{\cdot}38 \text{ shillings} \quad . \quad . \quad . \quad . \quad (2)$$

[1] See *Report of the Departmental Committee on the Rationing of Dairy Cows*, Ministry of Agriculture and Fisheries, 1925.

In this particular group of feeding stuffs then, the unit of starch equivalent costs 2·38 shillings, and the unit of protein equivalent 1·84 shillings.[1]

Applying these figures to a few feeding stuffs chosen at random, the following values per ton at the farm are obtained :—

	Starch Equivalent.	Protein Equivalent.	Value per ton.
			£ s. d.
Oats	60	7·6	7 16 10
Bean meal	66	20	9 13 10
Linseed cake	74	25	11 2 1
Palm kernel cake	75	17	10 9 9
Maize germ meal	85	10	11 0 8
Bran (wheat)	42	10	5 18 4
Meadow hay (average)	31	4·6	4 2 3
Oat straw	17	0·9	2 2 1
Swedes	7	0·7	0 17 11
Potatoes	18	0·6	2 3 11

In certain cases where the farmer requires only one or other of the valuable ingredients a simpler calculation will suffice. Thus, for example, a grazier with cattle fattening on clovery pasture has no need for protein and should buy whatever supplies starch equivalent at the cheapest rate. On the other hand a pig feeder with plentiful supplies of small potatoes and unmarketable barley should compare market feeding stuffs on the basis of cost per unit of protein equivalent, neglecting the energy value.

An additional factor in feeding stuff valuation is their manurial value. If it is desired to take account of these (as it will be wherever the manure is properly utilised), the manurial values of barley, maize, and the cakes may be deducted from their prices before the unit costs are calculated, and the manurial values of the individual feeding stuffs in the second list added to their feeding values as determined on the new basis.

[1] This does not imply that protein is cheaper than starch. A unit of digestible protein, apart from its value as protein, has an energy value of 0·94 unit of starch equivalent. The actual cost of the unit of protein is 1·84 + (0·94 × 2·38) or 4·08 shillings.

It is of course true that no feeding stuff can be cheap for a particular purpose if it is unsuited to that purpose. But if, for example, bean meal is offered at £12, 10s. per ton and palm kernel cake at £7, 10s. (as was the position when this was written), it is clear that the latter should be used in preference to the former wherever possible.

There is one other important general question in rationing, viz., that of the total bulk of the ration. On the one hand there is a fairly definite limit to the quantity of food (dry matter) that the animal is able to consume, and the necessary energy and protein must be contained in a quantity that does not exceed this maximum. On the other hand, too highly concentrated a ration, even if it contains the necessary nutrients, will fail to satisfy the animal's hunger and may have an ill effect on its general health. For cattle and horses the lower limit, say in the case of animals on a maintenance ration, is about 1½ per cent. of the live weight daily. The ordinary sort of production ration should contain a quantity of dry matter equivalent to about 2½ per cent. of the live weight. The higher limit is ordinarily under 3 per cent., except in such cases as those of a cow giving a very high yield of milk, or a lean store animal at the commencement of the fattening period, where the appetite is, naturally, very large. In such cases the upper limit is about 3 per cent. of the live weight. For sheep 2½ to 3 per cent. of the live weight is normal. With pigs a good general rule, in the case of production rations, is to arrange that the starch equivalent be about three-fourths of the dry-matter content. This means that where the ration consists of ordinary air-dry material (say 90 per cent. dry matter), the starch equivalent of the food as a whole should be about 65 to 70 per 100 lb. The actual consumption of dry matter, on full feeding, is considerably higher than in other classes of stock—about 4½ per cent. of the live weight for the young weanling (two months old), decreasing to about 3 per cent. at six months old and to 2½ per cent. at a year.

Broadly speaking, the appetite becomes less, in proportion to the live weight, with age, but ruminants during the

suckling period are an exception, because the paunch is quite small at birth. Thus young calves actually consume less dry matter, in proportion to their live weight, than cattle of greater age, and must have highly concentrated and easily digested food. Small individuals, other things being equal, eat more in proportion to their live weight than large ones. More detailed figures are given in the feeding tables in the Appendix.

There are several other matters that require attention in rationing; such, for example, as the palatableness of the food; its effect on the general health of the animal; its effect in producing costiveness or looseness; and its effect on the quality of the product—*e.g.* milk or bacon. These and other questions of a practical kind are dealt with in the special chapters on the various classes of stock.

CHAPTER III

CATTLE—TYPES AND BREEDS

THE term cattle, originally used to include all classes of live stock, is now generally restricted to oxen, which are included by zoologists in the genus *Bos*. This genus comprises the wild and domesticated buffaloes of Asia, and some two or three wild African species of buffalo; the American and the European Bison; the Yak of Thibet; three species of Asiatic cattle—the Gaur, Gayal and Banteng—all of which are found wild, while the last two are also kept under domestication; the domesticated humped cattle (Zebus) of Asia and Africa; and lastly our European domesticated types.

Domesticated cattle are known to have existed in Babylon as early as 5000 B.C. The earliest known domesticated type found in Europe is that known as *Bos taurus brachyceros* or *Bos longifrons*, a very small, slightly built ox with short horns, which was very widespread in the earliest Neolithic (polished stone) period. There is no evidence that it was evolved in Europe, and the accepted view is that it was introduced from Asia as an already long domesticated animal. This type, sometimes known as the "Celtic Shorthorn," persisted in Britain till Roman times, but on the Continent it was displaced much earlier by a large, strong-boned and long-horned animal known as *Bos taurus primigenius*. This seems to have been produced either by crossing the older form with the native wild species, or perhaps by direct domestication of the latter, the old type being meanwhile discarded. The European wild Ox or Urus (*Bos primigenius*) was common in Europe during the Roman period, and the last known specimen was killed in Poland in 1627. It was a very large and powerfully built animal with long horns, and probably brown in colour.

European cattle comprise a great variety of types. Quasi-zoological classifications of these types have been proposed, but none is very satisfactory. As regards the British breeds, they are of very varied and frequently of mixed ancestry. Thus the native cattle before the Roman invasion were small, black, or brown in colour, with short horns (*Bos brachyceros*). The Jersey, Kerry, and Shetland probably show the largest proportion of this blood. Then, according to Professor Wilson, the Romans brought in large white animals whose descendants were preserved as the "wild" white cattle of Cadzow, Vaynol, and Chartley. According to another view these park cattle are the direct descendants of the wild Urus. It is certain that the Anglo-Saxons brought over cattle—red cattle—whose purest modern descendants are the Sussex and the Devon. Possibly the Norse invasions gave us our polled breeds, though occasional polled animals occurred before that time. Much more recently, in the seventeenth century particularly, there was a large influx of large, short-horned and broken-coloured cattle from the Netherlands. These have had a large influence on the Shorthorn and Ayrshire, and probably a lesser influence on several others of our breeds.[1] These types of cattle have intermixed to a considerable extent, just as Celt and Saxon, Norman and Dane have intermixed to form our human population.

For practical purposes we classify cattle according to the object or objects for which they are kept, *i.e.*, for labour, beef, milk, or any two, or all three. In Britain oxen are scarcely used for work purposes, and therefore our classification is into beef, dual purpose, and dairy types. As a matter of fact there is a gradation of types from the Jersey, which is of practically no value as a beef animal, to certain strains of Shorthorns, Herefords, etc., that produce barely sufficient milk to rear their calves. Specialisation has been carried further in Britain and America than in most other countries. On the Continent

[1] See Wilson's *Evolution of British Cattle*, Vinton, 1909.

of Europe a considerable majority of breeds may be said to be dual purpose or triple purpose, and purely beef breeds hardly exist.

We must endeavour to analyse, as far as possible, the qualities that constitute merit in a beef or in a milking animal. The aim of course is not simply a high quality of meat or a large yield of milk; but beef or milk or both in such quantity and of such quality as will leave a maximum of profit to the producer. Our aim in breeding must therefore depend on the demands of the consumer, and it is of course true that these may change from time to time. An example of such change is to be seen in the demand for a small and young carcass with a high proportion of lean meat, as compared with the popular taste of a century ago for a larger, more mature, and very much fatter carcass. Nevertheless, the main points in a beef or dairy animal have a permanent significance.

It follows from what has been said in Chapter II. of this section that the efficiency of an animal, whether in the production of meat, of wool, of work, or of milk, depends on the ratio that obtains between the total food consumed and the quantity required for maintenance. The animal machine is always somewhat inefficient, because it must consume a certain amount of material before it begins to produce anything at all. An animal that eats no more than a maintenance ration has obviously an efficiency of zero. A dairy cow producing two gallons of milk daily, or a steer increasing in weight at the rate of two pounds a day, requires (very roughly) twice as much net energy as it would require for maintenance; and (since the surplus net energy is converted into milk or body fat) the efficiency will be roughly 50 per cent. A cow producing 4 gallons daily, and eating the equivalent of three maintenance rations, would have an efficiency of 67 per cent., and a 6-gallon animal an efficiency of 75 per cent. Thus the more our animal eats in proportion to its maintenance ration (so long as the food is thoroughly digested and the animal remains in health), the more economical does the productive process become.

Thus, whether for beef or milk production, we want a low maintenance requirement and a capacity to deal with large amounts of food. The maintenance requirement in cattle at rest has been found to be remarkably uniform in proportion to the animal's size (surface area), but in practice the non-productive consumption does vary to a considerable extent, because animals that are restless waste a considerable amount of energy in useless movement.

The second requirement in a beef animal is ability to store a large amount of fat, and to commence this process of storage at an early age, while growth is still in progress. Some animals eat largely when they are producing milk or when they are very lean. Their feeding capacity is sufficient to supply a large demand. But before sufficient fat has been stored to meet the needs of the butcher, the process of accumulation stops short, the appetite declines, and the animal reaches a state of equilibrium. Other animals feed well when mature, but refuse to fatten during growth. These we say are lacking in early maturing quality, the importance of which is obvious. The shorter the animal's life the smaller is the proportion of its total food that is spent in maintenance.

The other chief aim is quality in the product—the fat animal. This is to some extent a question of the percentage of meat in the animal as a whole. Beef is of far greater value, generally, than the other parts of the body, and hence the type of animal required is light of bone and hide and offal, and thickly fleshed. Some of these characters are, however, incompatible with other desirable qualities, *e.g.*, a light middle generally indicates a poor feeder. The proportion of the different cuts is also of importance. An animal with its weight concentrated in the back, sirloin, rump, and hind-quarter, which are the high priced cuts, will be much more valuable than another with a heavy neck and shoulder and a thin back. But here the differences that exist between different animals are not very large. The chief point that determines the quality of the beef is the manner in which the fat is stored. Many

unimproved breeds and dairy-bred animals tend to store the fat internally (for example, round the kidneys) and in a thick layer under the skin, the muscle tissues remaining relatively free from fat. The result is that the carcass is wasteful, and the lean meat when cooked is tough and dry. In good beef, on the other hand, much fat occurs within the muscles, which when cut across show a characteristic "marbled" appearance, and the meat when cooked is tender, juicy, and of good flavour. This tendency to store fat abundantly within the lean meat is probably the most important single quality in a beef animal. It is what the feeder means when he speaks of his animal "putting on flesh" during the fattening process. A minor point in connection with the quality of the meat is the colour of the fat. Most consumers object either to a dead white colour or to a deep yellow. Channel Islands cattle, for example, are characterised by a deep yellow colour in the body fat.

The points of a beef steer are shown in Fig. 57. The general type, which varies from breed to breed only in minor details, is a moderately long but deep and very wide block of meat on short legs. The head should be wide between the eyes and short from eye to nose; the muzzle large, the jaw strong, and the eye full and mild; the neck short, and full at its junction with the shoulder; the back wide, and almost uniform in width from crops to pin bones; the shoulder smoothly laid and well covered, not protruding from the general outline of the side nor having a depression behind it; the brisket full, the heart-girth large, and the ribs well sprung or rounded, the middle moderately large, but not "paunchy," and the flank well let down, *i.e.*, the underline nearly straight. The animal should be "well ribbed up," *i.e.*, the space from the last rib to the hook should be short; the hind-quarters long, wide, level, and fairly square in cut, with the hook bones not too prominent; the plates well filled with flesh, the tail-head level and the tail hanging perpendicularly; the thighs thickly fleshed and the flesh well carried down to the hocks; the twist or inner thigh

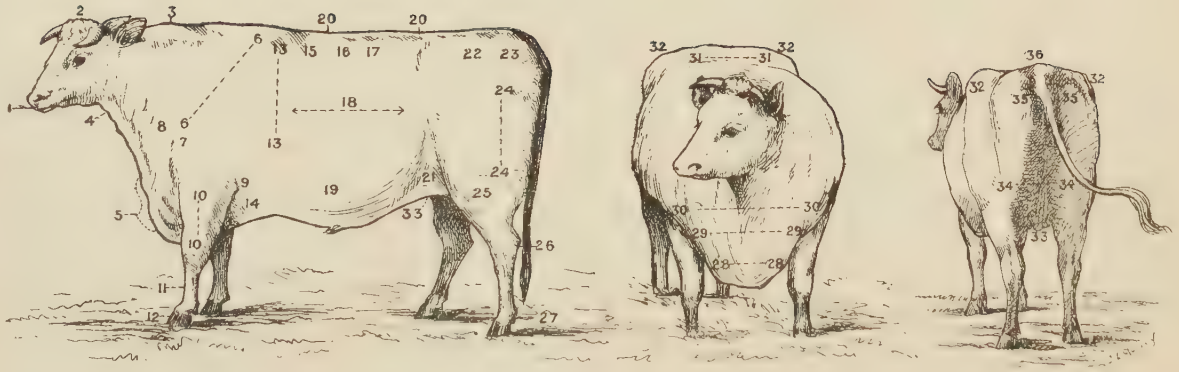


FIG. 57.—ILLUSTRATING THE POINTS OF AN OX. (After Thomson.)

1. Muzzle.
2. Poll.
3. Crest.
4. Throat.
5. Dewlap.
6 to 6. Shoulder.
7. Shoulder point.
8. Shoulder- or Neck-[Vein.
9. Elbow.
10. Arm.
11. Shank.
12. Hoof.
13 to 13. Crop
14. Fore Flank.
15. Fore Ribs.
16. Mid Ribs.
17. Back Ribs.
18. Barrel.
19. Belly.
20. Spine.
21. Flank.
22 to 23. Plate.
23. Rump.
24 to 24. Hip.
25. Thigh.
26. Hock.
27. Hind Leg.
28 to 28. Brisket.
29 to 29. Bosom.
30 to 30. Chest.
31 to 31. Loins.
32. Hooks or Hip-bones.
33. Purse.
34. Twist.
35. Pin-Bones or Catch.
36. Tail-head.

full. The animal should stand on short legs with fine but flat bone, and with the forelegs placed well apart. The flesh should be firm and resilient to the touch, not soft and flabby; the skin not too thin but soft and mellow to the touch. "Handling" is very important as an indication of feeding capacity. In judging commercial stores the chief points to look for are "well-bred" heads—*i.e.*, showing an approach to the type of some improved beef breed—wide backs, thick flesh, and good middles.

Turning to Milk Production, Eckles[1] has made an interesting analysis of the differences existing between a good and a bad Jersey cow. He found that there was very little qualitative difference in digestive capacity, *i.e.*, the two animals extracted practically the same quantities of nutrients from like quantities of particular foods. The maintenance requirement was not quite the same, but in the case in question the poorer cow had the advantage, *i.e.*, it maintained its weight when dry on rather less food than the better animal. In the investigation the cattle were fed for a year in such a manner that their body weights remained practically constant. The important conclusion was that the milk yield was proportional, not to the total ration, but to the amount of food eaten over and above the amount required for maintenance; and hence the heavier yielder was also the more economical producer. If we look for the causes of unsatisfactory yields it is obviously possible that these may be of two sorts. On the one hand, certain cattle milk well for a short time, but "milk down" in condition very rapidly and soon drop off in yield. Here it seems that the mammary capacity may be ample, but the digestive organs are not able to work at sufficiently high pressure to supply the necessary raw materials. The failure is in digestive capacity. On the other hand, there is the type represented in many cows of good beef form. They have ample feeding capacity, but the surplus food is diverted to body fat instead of to milk. If a heavy ration be fed to such an animal, it continues to fatten up to a certain point, when the appetite declines and a balance between the income

[1] See Eckles' *Dairy Cattle and Milk Production.*

and expenditure of energy is restored. In this type it may simply be that the mammary system is not of sufficient capacity to deal with the available nutrients, and that, failing an outlet as milk, the surplus nutrients are converted into body fat. This on the whole appears likely. But, on the other hand, it is possible that there is a kind of competition for the available nutrients between the fat-storing cells of the body and the mammary cells, and that, in animals that have a marked tendency to fatten, the process of storage tends to take precedence over that of milk production. In this last case we should have to regard the fattening tendency as definitely opposed to high milking capacity. Unfortunately there is no evidence on which to reach a definite conclusion. Some deep-milking cattle do, however, fatten readily when dry.

The activity of the mammary tissues depends, of course, on the stimulus of parturition, and a new cycle begins with each calving. The yield during the lactation may be determined, to a considerable extent, by the amount of response to this stimulus, which is believed to be caused by internal secretions. Hence these secretions may have an important bearing on milking capacity.

The degree of importance attaching to the quality of milk depends on the mode of utilisation. Where whole milk is sold, all that is necessary is that the milk should conform (with a reasonable margin of safety) to the British presumptive standard of 3 per cent. butter-fat[1] and $8\frac{1}{2}$ per cent. of other solids. Only occasionally can a market, at a higher price, be found for milk of superior quality. On the other hand the yield of butter or of cream depends mainly, and the cheese yield depends very largely, on butter-fat content; so that for these purposes the composition of the milk is important and attention must be given to the matter in breeding. There is a slight negative correlation between butter-fat content and yield, *i.e.*, cattle that give rich milk are generally somewhat smaller producers than those that give poor.

[1] In Scotland the standard for certified milk is 3·5 per cent. of butter-fat.

It will obviously be difficult to translate the physiological qualities that go to make a good cow into terms of bodily points, and, as a matter of fact, the judging of milch cattle from their appearance is at best an unsatisfactory business. The real test is actual performance, with due allowance for age and the other conditions that are known to affect yield. The mean yield over a series of lactations and under ordinary farm conditions is the best kind of record. Failing this we must take the record of a shorter period and endeavour to form an impression, from the cow's appearance, of her constitution and general ability to live and thrive in the average environment of her breed.

Of the outward signs of milking capacity the most reliable are the size and "quality" of the udder. The udder should be large, extending well forward along the belly and well backwards and upwards. It should also be wide and deep. A pendulous udder, if short and narrow, is often far less capacious than it appears. The udder should be composed of actual secreting tissue, which is elastic, so that the udder is large before milking and has a shrunken appearance and a soft pliable feel when empty. The teats should be placed well apart and of a convenient size for grasping, *i.e.*, say from three to four inches long. After the udder, the size of the milk veins, which extend forward from the udder along the belly, is probably the surest guide among the external characters. A capacious middle, as showing ability to feed, is also a point of some importance, and a quiet, docile temperament, as indicated by the head, eye and general behaviour, is desirable.

The conventional "ideal dairy cow" has many other points that are considered to be indications of deep milking qualities, but the value of many of these is doubtful, and there is no conclusive evidence in favour of any of them. Many cows of "dairy type" are good milkers, but others that are poor, as judged by the accepted standards, milk well nevertheless. Briefly, the "ideal dairy cow" is wedge-shaped, *i.e.*, she is narrow in the fore-end, with sharp withers, and wide in the hind-quarters; also, she is relatively shallow

in front and deep behind. The horn should be fine and have a waxy appearance, the eye large and placid, the head broad between the eyes, rather longer than in the beef type, and lean; the neck should be long, thin, and muscular, the shoulder light and sloping, the withers sharp and narrow; the chest must be of fair depth and not too narrow, otherwise the animal is likely to be lacking in constitution; the middle should be large, the ribs deep, well sprung, and placed wide apart, with a wide space between the last rib and the hook; the hind-quarters should be lengthy and wide, particularly at the pin bones; the thighs should be thin, and the tail long and fine. Generally, the animal should be thin in flesh, having a somewhat angular but refined appearance; the skin should be thin, soft, and elastic. The colour of the milk is indicated by that of the skin as seen, for example, inside the ears and on the end of the tail. Animals that have deep yellow skin generally give deep-coloured, rich-looking milk. The escutcheon, or area of reversed hairs on the back of the udder, is sometimes regarded as an indication of yield. Statistical investigation has, however, quite failed to give any support to the theory.

Dairy type is somewhat differently interpreted in the several dairy breeds. The most extreme type is suited only to the best conditions. It is recognised that cattle which are expected to withstand harsh weather or survive periods of scarcity must be rather less refined in form and carry more flesh than the "ideal" dairy cow.

Unreliable as some of the "signs of milk" are when applied to the cow in milk, they are of still more doubtful value as a measure of the hereditary milking qualities in the bull. The only proved measure of a bull's worth is the performance of his female relatives, whether dams, sisters, or offspring.

The dual-purpose type represents an endeavour to combine milk production in the breeding cow with good fattening qualities in the males and non-milking females of the breed. The recent development of dual-purpose types, *e.g.* in the Shorthorn, has been regarded by some as a retro-

grade step: they regard specialisation as essential to the progressive improvement of live-stock and look upon the dual-purpose animal as at best an unsatisfactory compromise between two essentially opposite types. But there is no proof of actual incompatibility between deep-milking qualities and the tendency to fatten when not in milk, and it is in fact possible to combine, to a considerable extent, beef qualities and milking tendencies in the same animal. In any case it would seem that dual-purpose cattle are an economic necessity, for under intensive conditions there can be no cheap or abundant supply of calves for rearing except those bred from dairy cows. The efforts that are being made to fix and perpetuate the combination of qualities are meeting with a large measure of success.

Breeds of British Cattle.

There are, all told, twenty-two breeds of British cattle, each of which has a separate herd book. No classification can be altogether satisfactory, because each breed shows a certain amount of variation in type from herd to herd, according to the purpose for which the herd is kept, the method of management, and the fancy of the particular breeder. Thus there have been dairy herds of Herefords and beef herds of Friesians. We may, however, fairly accurately classify the Hereford, Aberdeen Angus, Sussex, Galloway, and West Highland as beef breeds. The Devon might also be included, but it embraces rather more dairy herds and would seem to be developing along dual-purpose lines. There are six dairy breeds, the Friesian, Ayrshire, Jersey, Guernsey, Kerry, and Gloucestershire, of which the first is the nearest approach to the dual-purpose. The remainder, excepting only the Shorthorn, are dual-purpose. They include the Lincoln Red, Red Poll, South Devon, Longhorn, Belted Galloway, Blue Albion, Welsh Black, Dexter, and White Park. The Shorthorn consists of two main types, the Beef, represented largely by animals of Scotch blood, and the Dairy Shorthorn which is really a dual-purpose animal, or at least is judged from this stand-

point at the leading shows. The breed includes, however, a large variety of types from the pure beef strains to others that can be described quite definitely as dairy cattle.

The Shorthorn [Plate I.] originated in a number of closely related types that existed during the early eighteenth century in Yorkshire, Northumberland, and Durham. The centre of most of the early work of improvement was the area within a radius of about twenty miles of the town of Darlington. The ancestry of these foundation types, while not fully known, appears to have been very mixed. The blood of the old black Celtic, of the red Anglo-Saxon, and of the broken-coloured Dutch cattle seems to have been blended in them. There are definite records of importations from Holland as late as 1750, and it is certain that there were many others of earlier date. The cattle of Teeswater, a century and a half ago, were held in high esteem both for beef and milk, perhaps more especially the latter. They were of large size, short horned, and of mixed colours, with red-and-white predominating. The Holderness breed was described in 1743 as having "wide bags, short horns, and large bodies, which render 'em (whether black or red) the most profitable beasts for the dairy-man, grazier, and butcher."

Some careful selective breeding had been done before 1750, but the earliest of the great improvers were the brothers Charles and Robert Colling of Ketton and Barmpton, near Darlington, who commenced farming about 1780. They selected the best available animals of the Teeswater type, devoting special attention to fattening qualities, and they inbred very closely. At Charles Colling's famous sale in 1810 the very much inbred bull Comet realised 1000 guineas.

The Booths of Killerby and Warlaby in Yorkshire were also, for three generations, famous improvers. They used Colling bulls in the early stages, and produced a type of animal notable for its substance, wide back and thick flesh, but of little account as a milker. Booth cattle were very prominent in the showyard, and were highly prized, over the long period from 1840 to 1880. Thomas Bates of

A. Shorthorn Bull, "Star of Morning"

["*Agricultural Gazette Photograph*"

B. Dairy Shorthorn Cow, "Fair Rosamond"

[*G. H. Parsons, Alsager, Cheshire*

A. Aberdeen-Angus Bull, "Wizard of Maismore"

B. Hereford Bull, "Mansel Handyman"

Kirklevington commenced breeding in 1800, and originated a type of Shorthorn that rivalled the Booth in popularity. His ideal was a dual-purpose animal, and he attached great importance to handling qualities, to style and character, and to particular blood lines. He inbred very intensively, and, probably as a consequence, many of his females during the latter period of the herd's existence were barren. Twenty years after Bates' death, which occurred in 1849, his cattle enjoyed a great boom and brought extraordinary prices. After 1890 they fell from favour, but now again Bates' blood is in high esteem among breeders of the dairy type.

The Scotch Shorthorn is mainly the product of the efforts of Amos Cruickshank (1808-1895) of Sittyton, Aberdeenshire. He was no partisan of the Booth or of the Bates type, and founded his herd by selecting good animals of very varied breeding, Booth blood, on the whole, predominating. His special aims were a robust constitution, good middle, thick flesh, early maturity, and feeding qualities generally. The Scotch type rose very rapidly in favour, first in the United States and, after 1890, in Britain. It remains the favourite among the beef strains, nd has no pretensions to dairy qualities.

All British Shorthorns are registered, without regard to type, in Coates's Herd Book, established in 1822. This is an "open" register, *i.e.*, animals are eligible for entry if they have a certain number of registered crosses, and need not be descended from registered parents on both sides. The regulations require, for females, four crosses of registered blood, and for males five, so that it is possible by the use of registered bulls for four or five generations to grade up non-pedigree herds until all their members are eligible for entry. Any registered animal may compete in the classes for "Shorthorns" at the leading shows, but males can only be shown in the "Dairy" classes if their dams have passed certain specified milking tests.

The special breed points are as follows:—Colour: red, or red and white, or white, or roan. Deep cherry red and

deep uniform roans are preferred; patchy roans, red and white, and yellowish or gingery red and roan are regarded as objectionable. The muzzle should be flesh coloured, a black or cloudy nose being very undesirable. The horn is short, laterally flattened, of fine waxy texture, and free from black. It should not curve upwards, but only forward in the male and forward and inward in the female, remaining about level with the crown. The coat should be thick and abundant. In weight the beef Shorthorn stands second to the South Devon among British breeds. The dairy type is rather smaller in frame than the Friesian, but nearly of the same weight. The beef Shorthorn, as compared with most other beef breeds, is characterised by greater squareness of conformation, the back being very wide and flat, and the quarters very square. The Angus, for example, is much more cylindrical in form, with a more rounded buttock. The dairy type shows generally a large and fairly symmetrical bag with well-fleshed back and hind-quarters. The better sort of herds reach average annual yields of from 7000 to 8000 lb. for cows and heifers of all ages; individual yields of over 10,000 lb. are common, those of over 20,000 rare. The butter-fat content averages about 3·7 per cent., but of course varies as it does in all breeds.

The Shorthorn takes pride of place among all breeds for general utility. It is very widely adaptable to all kinds of conditions, and is very valuable in the grading up of inferior stock. It has been largely exported to nearly all cattle countries, and is very numerously represented in both North and South America. There are Shorthorn herd books in France, Argentina, and North America.

The Lincolnshire Red Shorthorn, or Lincoln Red, is a strain of Shorthorn found chiefly in its name-county. It is of a whole cherry-red colour, large in frame, and of robust constitution. In the main the breed is a dual-purpose one, but it contains strains of beef type. Many excellent milk records have been made by the cows.

The Aberdeen Angus (Plate II. A.) originated in the old local breeds of Forfarshire (Angus) and Aberdeenshire. As

far back as records go, which is to the middle of the sixteenth century, a proportion of these cattle have been black and hornless, characteristics that have now been practically fixed in the breed. Red calves, and others with white markings, are dropped occasionally, but horns have been completely bred out. The earliest improver was Hugh Watson of Keillor, near Coupar-Angus, who laid his foundation in 1808. Of the other breeders in both counties who carried on the work, the greatest was William M'Combie (1805-1880) of Tillyfour in Aberdeenshire, who not only improved the breed, but succeeded in making its merits generally known. The chief breeding district is still the country lying between Inverness and Perth and eastwards to the sea, the breed being restricted in the more mountainous parts of this region, to the straths and glens. Speyside has very numerous herds. There are now many Angus herds throughout the arable districts of Scotland and also in most counties of England and Ireland. The herd book, established in 1862, is a closed register, *i.e.*, no animals may be entered except such as are the progeny of parents already registered.

The Aberdeen Angus is black in colour, with a brownish tinge in the winter coat and in that of the calf, and with often a little white on the underline behind the navel. It is hornless, with a somewhat sharply-pointed poll. The Shorthorn, Hereford, and Sussex all exceed it in size, but the difference in weight is less than it appears, as the Angus is compact and heavy for its size. The Smithfield weights show that the breed is actually about 4 per cent. lighter than the Shorthorn. The bone is small, and the general symmetry and smoothness of outline are marked characteristics. The back and also the buttock are somewhat more rounded than in the Shorthorn, and the hooks scarcely project from the general line of the side.

As a commercial animal the Angus is an early maturing beef beast of superlative quality. The dressing percentage is high, the carcass is very free from patchiness, and the beef is fine in grain and well marbled. In open competition at the larger fat-stock shows and in carcass competitions during

the past thirty years the breed and its crosses have won more championships than all others together. The yield of milk, though irregular, is high for a beef breed, and cows with really good dairy qualities occur. The temperament is rather more active than that of most beef breeds.

The Angus is particularly well adapted for intensive feeding and for "baby beef" production. It has not proved so widely adaptable as the Shorthorn, nor so useful under poor range conditions as the Hereford. For grading up thin-fleshed and slow-maturing types it is less useful than the Shorthorn, but for imparting quality to herds that are already improved to some extent, it is excellent. It has been an outstanding success under arable or semi-arable conditions, for example in the maize-growing districts of the United States. It has been exported in large numbers. Crossed with a white Shorthorn, the Angus produces the well known and highly valued blue-grey.

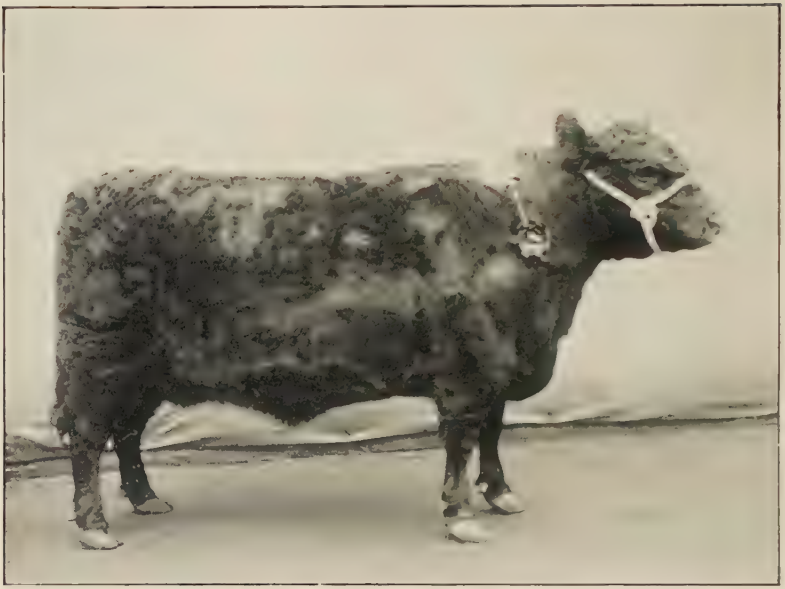
The Hereford (Plate II. B).—As early as the beginning of the seventeenth century the cattle of Herefordshire were held in high esteem both as work oxen and for beef. They were large, stoutly built, hardy, and generally well suited to be reared and fattened on the fine pastures of the county. Improvement in the direction of early maturity and quality of meat began early. The names of Benjamin Tomkins the younger (1745-1815) and of John Hewer (1787-1873) are the best known, the one amongst the older, the other in a more recent generation of breeders. The herd book was established in 1846, and has been closed since 1883.

As regards Britain, the Hereford is rather a local breed. Nearly all the prominent pedigree herds are found in the English and Welsh counties adjoining the border, from Cheshire in the north to Monmouth and Gloucestershire. The Royal herd at Windsor is a notable exception. The breed is, however, largely represented in Ireland, and has a large place in the United States, Canada, South America, and Australia. The breed characteristics are a large size (little inferior to that of the beef Shorthorn), a deep rich red colour, with white head and underline, and generally a narrow

A. Sussex Bull. "Sundridge"

["*Agricultural Gazette Photograph*"

B. Devon Bull, "Pound Larken"



A. Galloway Heifer, "Lady Glen"

[*Lent by Highland Society*

B. Highland Heifer, "Caroline II"

band extending along the upper part of the neck and over the crops. Some cattle have a red spot at the eye, which is an advantage in countries of glaring sun. The horn is of medium length, slightly drooping and of a waxy texture; the back is wide and thickly covered, the chest deep and capacious, and the legs short. The skin is thick but mellow, and the coat mossy and very dense and abundant. The Hereford has not the superlative quality of meat of the Angus, nor is it distinguished, even among the beef breeds, for milking qualities. Its chief value rests in the fact that it has, of all breeds, the fullest combination of early maturing and fattening qualities with a robust constitution. It is an excellent "doer" under pastoral conditions, will fatten readily on good grass alone, and abroad has been found to live and thrive on the poorer and drier type of range where no other improved breed can exist. In their home country the cattle are very generally kept out of doors throughout the year, and as a consequence the breed is relatively very free from tuberculosis.

The Sussex (Plate III. A) is native to the Weald district and the marsh lands of Kent, Surrey, and Sussex. It is believed to represent the pure Anglo-Saxon type. The breed was originally kept mainly for draft purposes, and continued to supply work oxen for the Wealden clays long after the horse had become the sole draft animal elsewhere. With changing conditions the Sussex has become a beef breed, but it still bears some traces of its centuries-long use in the plough. In weight it is practically equal to the Hereford, but it is less compact, somewhat more muscular in build and rather later maturing. The colour is a deep red, the horn fairly large and spreading, the skin fine, and the coat rather short.

The general conformation is that of a good beef animal, the quality of the beef is excellent, and in hardiness and ability to thrive on poor fare the breed is outstanding. It has met with considerable success in South America. The herd book was established in 1874.

The Devon (Plate III. B) is native to the hilly region in

the north of Devonshire, but spread at a very early date into the adjoining parts of Somerset. Many descriptions dating from the latter part of the eighteenth and early nineteenth centuries show that the breed existed in those days in a form not unlike the modern type. The Devons were described by Marshall (1796) as "the best workers he had ever seen," and by John Lawrence, in 1805, as having "for a century past commanded the best price at Smithfield." All writers agree that they were hardy, excellent draft animals, and good feeders. Francis Quartly (1764-1856) of Great Champson, Molland, was the greatest individual improver. During the period between 1793 and 1823, when war prices tempted many of the breeders to sell their best cattle and to slaughter their calves for veal, he gradually got together a herd of the best individuals he could find. By continued selection and inbreeding he produced a strain that has since been regarded as the fountainhead of all the best blood.

At the present time the Devon is most numerously represented in North Devon and Somerset, though herds are scattered fairly widely over southern England. On the lower and more fertile pastures of Somerset the cattle are larger and of greater substance, but lack to some extent the refinement of the upland cattle. In appearance the Devon rather closely resembles the Sussex, but is considerably smaller, of a rather brighter shade of red, with very frequently dapple markings. The horns are of moderate length, with an upward tilt in the female. General symmetry of build and smoothness of flesh are marked characteristics. The breed is hardy, well adapted for grazing, and produces beef of choice quality. In recent years more attention has been devoted to dairy qualities, and milking classes for the breed have been established at the London Dairy and Royal Shows. Several pedigree herds are kept for dairy purposes. The breed has met with considerable success abroad, particularly in semi-tropical countries.

The Galloway (Plate IV. A) is an old breed of obscure origin. Two hundred years ago it occupied, to the almost complete exclusion of other breeds, a very large area in the

south-west of Scotland. The extension of dairying in this district has caused it to be largely displaced by the Ayrshire, but, on the other hand, it has extended into the north of England, and has won a place for itself in Canada and the United States. Like the Aberdeen Angus, the Galloway is black (occasionally dun) and polled, and of beef type; otherwise it has few points of similarity with the northern breed. In the Galloway the head is very short, with a broad poll, and with the ears set on rather low; the neck is rather long, the body deep, but lacking the great width of some of the most highly-developed beef breeds. A certain slackness of back and prominence of shoulder are common faults among the ordinary commercial individuals. The skin is thick and the coat very abundant, consisting of a very dense mossy undercoat with an outer covering of long fine hair.

The Galloway is one of the hardiest of breeds, whether under the cold and very wet conditions that obtain in winter among its native hills or in districts of intense winter frosts. The cows of most herds live out of doors throughout the year, being brought to lower ground in winter and returning to the higher altitudes soon after calving. The quality of the meat is excellent, and the carcass is never patchy nor wasteful from excess of fat. In recent years the breed has achieved great success in the Carcass Competitions at Smithfield Show. The Galloway is, naturally, a somewhat slow grower and feeder, yet wonderful examples of early maturity are often seen at fat-stock shows. Judged by the Smithfield weights, the Galloway is nearly 15 per cent. lighter than the Shorthorn at the same age. The Polled Herd Book was originally started as a common register for Aberdeen Angus and Galloway cattle, but a separate Galloway Herd Book was started in 1877.

Crossed with the white Shorthorn the Galloway produces a "blue-grey" that is hardier, if somewhat slower in maturing, than the corresponding Angus cross, and equally esteemed for the quality of its beef. The Galloway is not noted for dairy qualities, though deep-milking cows do occur.

The Belted Galloway is a distinct strain of the breed, separately registered. It has a characteristic white belt round the middle of the body and is more accurately described as a dual-purpose than as a beef type.

The West Highland (Plate IV. B), or Kyloe, is the native breed of the Western Highlands and Islands of Scotland. The recognised colours embrace various shades of red, yellow, dun, and cream, as well as brindled and black, which last formerly prevailed but is now rare. The breed is of moderate size, with large spreading horns and a shaggy coat of straight or slightly wavy hair; the form is square and deep, but somewhat lacking in width. It is exceedingly hardy and well adapted to live out of doors in the wild and exposed surroundings of its home country, where it can subsist on the poorest of grazing. It is a slow grower and feeder, the steers being rarely marketed fat until they are three-and-a-half years of age. The beef of well-fattened beasts is of choice quality. The milk yield is low, being little more than sufficient for the rearing of the calf.

Dual-Purpose Breeds.

The Red Poll (Plate V. A) of East Anglia was produced by the blending of two pre-existing local types, viz., the Norfolk Horned, a small and compactly built red beef breed, and the Polled Suffolk Dun, which is frequently praised by the old writers for its exceptional dairy qualities. The blending was carried out on a systematic plan and with the avowed object of producing a "new sort" of dual-purpose cattle. The work began in the first decade of last century, when two breeders, John Reeves and Richard England, both of Norfolk, began on the lines indicated. About the same time a Mr George, farming in the same county, founded a herd of red individuals selected from among the Suffolk Polled cattle. The breed was first recognised by the R.A.S.E. in 1862, and an admirably conducted herd book was started twelve years later. The Red Poll is still far commoner in Norfolk and Suffolk than elsewhere, but there are herds in almost every part of England and a few in Scotland.

["*Agricultural Gazette Photograph*"

A. Red Poll Cow, "Gressenhall Molly"

["*Agricultural Gazette Photograph*"

B. South Devon Cow, "Worsewell Profit"

A. Welsh Black Bull

B. British Friesian Cow, "Petygards Ciros"

The colour is a uniform red, with frequently some white on the udder of the female, and a white switch. In size the Red Poll equals the Angus, though it carries rather less flesh and is therefore lighter. Horns or "scurs" are not permitted, and a dark nose is regarded as very objectionable; both of these departures from type are rare. Generally, the Red Poll is a well-built and symmetrical dual-purpose animal, although the udder is often not so shapely as could be wished. In the past there has been some irregularity of type due to the varying importance attached by individual breeders to beef conformation and milking qualities respectively, but rapid progress in the direction of uniformity is now being made. The steers fatten readily at an early age, and produce a good quality of beef. In yield and quality of milk many herds compare favourably with those of dairy breeds. Good mature cows will give 8000 lb., and many high individual records, up to twice this amount and more, have been made. As a "farmers' cow," particularly on moderately poor land, the Red Poll is a valuable animal. It is popular and numerously represented in the United States and in South America, while there is a growing demand from many of the British Colonies.

The South Devon (Plate V. B) is numerously represented only in Devon and Cornwall. It differs very markedly from the Devon in being of a very distinct light brownish-red colour and of much greater size. The South Devon is, in fact, the largest of British breeds, cows in ordinary breeding condition frequently scaling 14 cwt., and bulls in show condition having been known to reach 30 cwt. The general type, according to the ordinary standard of cattle judges, is rather coarse. Improvement is of comparatively recent date, and a herd book was instituted only in 1891. Milk yields of over 1000 gallons have been obtained, and cows of the breed have done well in recent open milking trials. The percentage of fat is somewhat above the ordinary. The breed has been largely exported to South Africa, where it is exceedingly popular on account of its suitability to the climatic conditions and its usefulness for producing trek oxen.

The Longhorn was, in Bakewell's time, very widespread over the west midland and western counties of England, from Westmorland to Somerset and from Shropshire to Leicestershire. The best types were found in Lancashire and in the Craven district of Yorkshire. At the same period the breed was very widely distributed in Ireland, but whether introduced from England or not is unknown. Before it passed through Bakewell's process of improvement the Longhorn was a large and powerfully built animal that produced good draft oxen and fair milch cows. It had a rough shoulder, flat sides and large bone, was a slow feeder, and produced a dark coloured and coarse carcass. At the sacrifice of its dairy qualities Bakewell made it an early maturing beef breed of greatly improved quality, though even in Bakewell's beasts the fat was not too well laid on and the meat was poorly "marbled." In the middle part of last century the breed was all but driven out of existence by the Shorthorn, but since that time there has been a slow revival. The breed is now found principally in Warwickshire and the adjoining counties. On the poorer sorts of clay land it has proved a useful dual-purpose animal. Under these conditions it is hardier than the Shorthorn, and gives a creditable yield of milk of good quality. The breed is of medium size, still somewhat rough in conformation with long and, generally, drooping horns. The favourite colour is a dark red brindle, and the characteristic markings include a white stripe along the back, a good deal of white on the underline, and a white spot on the thigh.

The Welsh Black (Plate VI. A).—The black horned cattle of Wales are of great antiquity, although there is evidence that cattle of other colours have existed in the Principality along with them from medieval times. Formerly two breeds were recognised. The North Wales or Anglesey was a hardy, slow-maturing beef breed, well known for the past two centuries as producing the highly-valued grazing cattle imported into the Midlands for fattening, under the name of "Welsh Runts." In the south was the Pembroke or Castlemartin breed, rather longer and looser of frame and

thinner of flesh, prized chiefly for the dairy. The herd books were amalgamated in 1904, when the breed name of Welsh Black was adopted. The type is as yet not uniform, but the two branches are now converging towards the common ideal of a hardy dual-purpose breed. Of medium size (about similar in this respect to the Red Poll), the Welsh carries rather long, spreading horns. Show specimens often leave little to be desired in respect of symmetry, but the ordinary run tend to be heavy of shoulder, high at the rump, rather weak in the thighs, and hard "handlers." The steers are generally marketed fat at three years old, when they produce a carcass that is full of lean meat and of very high quality. On poor pastures, with little or no artificial food, and little except hay in winter, the cows produce very creditable yields of milk. Owing to their capacity to live out of doors in exposed districts and on poor fare, Welsh cattle must be regarded as indispensable to their native country.

The Blue Albion has its home in the high peak district of Derbyshire. It seems to have originated from an admixture of Shorthorn and Welsh blood, but a good deal of Friesian influence can be traced in many herds. The general type approaches that of the Dairy Shorthorn, but the recognised colour (which, however, seems not to breed true) is blue or blue-roan with more or less white. The breed has something of the hardiness of the Welsh, and many of the cows are deep milkers. A Breed Society was formed in 1919.

Park Cattle.—The Park Cattle or "Wild White Cattle," whose origin has been the subject of much discussion, are now under a Breed Society, have a herd book, and have obtained recognition from the Royal Agricultural Society. The cattle are white with black or red "points." Some herds are polled and others horned. The general type is dual-purpose, and the breed has several records of over 1000 gallons to its credit.

Dairy Breeds.

The British Friesian (Plate VI. B) is a branch of an ancient breed that has its home in the Dutch province of Friesland, lying north-east of the Zuider Zee. It is only one of several Dutch breeds, but is probably the most highly improved, and certainly possesses the most pronounced dairy qualities. Dutch cattle of the Friesian type have exerted a large influence on other breeds, including our own Shorthorn and Ayrshire as well as a great number of the lowland breeds of Western Europe. At the present time the Friesian is second only to the Shorthorn in its wide and general distribution throughout the world. The home province consists largely of low-lying and fertile pastures, and the special centre of the breed, the district round Leeuwarden, is one of exceptional fertility, though its climate is distinctly raw and cold.

During the second half of last century large numbers of black-and-white Dutch cattle, both Friesians and animals of the closely related North Holland type, reached Britain. The cows were chiefly bought for town dairies, and only a small proportion were in consequence kept for breeding, but a number of herds were established in the early seventies and again about 1890. Few of these were kept strictly pure or managed with any particular care, and the breed, as a whole, made little progress until the Breed Society was established in 1909. Thereafter it advanced in favour with extraordinary rapidity, and the membership of the Society increased from 50 in 1911 to 1600 in 1921. The foundation stock was accepted for the herd book by inspection, and it was impossible to prevent the admission of a proportion of animals of doubtful ancestry. This initial difficulty has since been largely overcome by very strict insistence on the true Friesian markings and type, and by the importation from Holland in 1914, and from South Africa in 1922, of a number of specially selected animals. The herd book is still open. Approved black-and-white cows are entered in a special register (A), and their progeny by registered bulls are

recorded, after inspection, in separate sections (B, C, and D) for the successive generations. Cattle with four "top crosses" of registered blood are then accepted for the herd book. The intention is, however, to close the "A" register at an early date.

The Friesian is by much the largest of the dairy breeds. The colour is black and white in clear and distinct patches. Dun and white, an old Friesian colour, is still accepted in the female, and, as in other black breeds, red calves are sometimes dropped, though very rarely. The feet and switch must be white, and a white star or blaze on the forehead is popular and of frequent occurrence; the head is rather long, the horns short and small, with a forward and inward curve; the hind-quarters are exceptionally wide, and the animals carry more flesh on the back and thighs than do most dairy cattle. The mammary system shows great development, but the udder is less square and regular than in the Ayrshire. The breed has sometimes been regarded as rough in conformation and lacking in quality, but this defect is being largely eliminated.

The special merit of the Friesian lies in its great milking capacity. In Britain, as in the United States and elsewhere, the breed holds all the records for quantity. In this country many individual yields of from 2000 to over 3000 gallons have been recorded, and large herds have averaged over 1000 for cows and heifers together. The breed has provided nine-tenths of the total number of official records of 2000 gallons or better in a year. The fat content of the milk is commonly lower than with other breeds. In Holland the average was at one time as low as 3·1 or 3·2 per cent. In Britain, while occasional animals fail to reach the 3 per cent. standard, the average would be more nearly 3·5. There is of course much individual variation, and a little careful selection will usually succeed in bringing a herd average up to the normal of 3·7 or 3·8.

As a meat producer the Friesian is by much the best of the purely dairy breeds, if it be considered as such; but it is not so satisfactory as, say, the recognised type of Dairy Shorthorn. The calves are large and feed rapidly

into excellent veal, but the steers tend to grow too large before they will fatten, and the meat is commonly rather poorly marbled. Some strains might be classed as dual-purpose, and a few steers of excellent quality have been exhibited at recent fat-stock shows.

The Friesian is quite ordinarily robust and hardy, but is pre-eminently suited to the better sort of pastures or to arable dairy farms where food is abundant. On poor upland pastures it has been found that it cannot successfully replace the Ayrshire.

The Ayrshire (Plate VII. A) came into existence some time before the end of the eighteenth century, but of the methods by which it was evolved we have no clear idea. The native cattle before the new improved breed displaced them were miserable beasts, "few of the cows yielding more than from one and a half to two gallons in the day, at the height of the season, or weighing when fat more than 20 stones." Teeswater, *i.e.*, early Shorthorn cattle, were imported, and possibly other cattle of more immediate Dutch extraction. There are traditions, too, of "Alderney" (*i.e.*, Channel Islands) cattle having been introduced. The centre of improvement was the parish of Dunlop, and John Dunlop of Dunlop was one, and probably the greatest, of the early breeders. The breed, as it spread over the northern portion and finally over the whole of the county, was successively known as the Dunlop, the Cunningham, and the Ayrshire. It began to be generally recognised as a distinct and improved breed about 1800, and has ever since been famous as a milker. Thus among the less extravagant estimates of the average yield is that of Sir John Sinclair who, in 1813, reckoned it at 900 gallons, and that of Low, in 1845, who states that "healthy (mature) cows on good pasture" should give between 800 and 900. During recent decades some strains of Ayrshires deteriorated owing to the neglect of dairy qualities for show points. On the other hand the milk-recording scheme initiated by John Speir, in 1903, has had a very beneficial effect on the utility qualities of the breed.

The Ayrshire is a comparatively small breed, cows in ordinary breeding condition scaling between 8½ and 9 cwt., or, say, four-fifths of the average Friesian weight. Cattle on poor upland farms are of course lighter than those found in the more fertile districts. The colour is red or brown with a varying amount of white, a large proportion of white being fashionable. Black and white is rather common among commercial cattle, but is not in favour. The horns are rather large, set on fairly wide apart, and have a very characteristic upward curve. The conformation is very symmetrical and neat, the back being straight and the lines of the body smooth. The udder is also characteristic, being of great length and width, firmly attached (not pendulous), level in the sole, with small teats squarely and neatly placed. It is certain that the fashion for "tight" vessels and small teats has in the past been carried too far, to the detriment of real utility. On the poorer sorts of land, at high elevations and in cold climates, the Ayrshire is a very valuable dairy animal. The general average of all the yields recorded in recent years is over 600 gallons, with about 3·8 per cent. of butter-fat. Several herds (whole herds, including frequently 20 or 25 per cent. of heifers) have averaged over 800 gallons with a butter-fat content of 4 per cent. or better. Individual yields of 1000 gallons and over are common, so that, in view of its small size, the Ayrshire must be regarded as a highly economical producer of milk. The fat globules are small, so that the milk "creams" slowly, which is an advantage for cheese-making. For beef the Ayrshire is of little account. There is a general concensus of opinion that the male calves are neither worth rearing for beef nor feeding for veal, although the quality of the finished steer is fairly satisfactory. Crosses by Shorthorn, Angus or Galloway bulls are frequently bred and make very fair butcher's beasts.

Ayrshires are largely kept in Canada and the United States, Sweden, Denmark, South Africa, and New Zealand.

The Jersey (Plate VII. B), which is believed to be of

French origin, has existed on its native island for centuries, and no foreign blood has been permitted to be introduced since 1763. A mild and equable climate and a fertile soil render the island very suitable for intensive dairying.

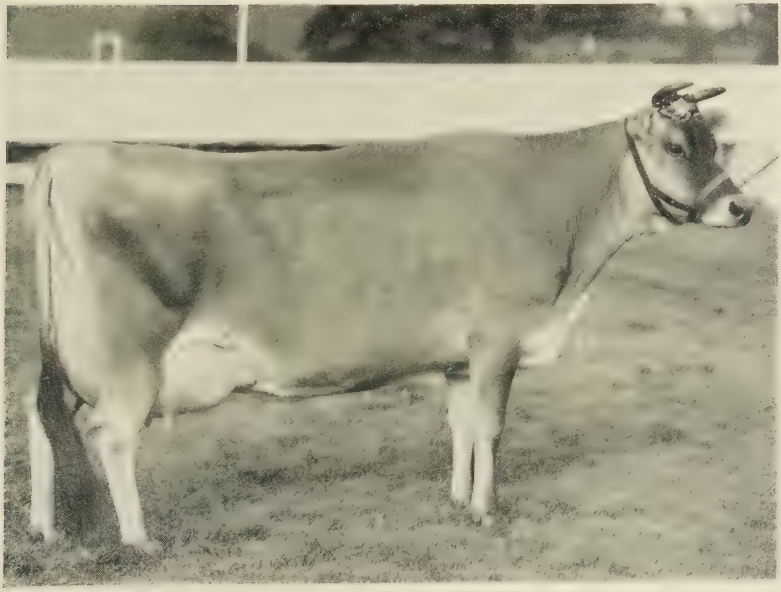
The Jersey is a small breed, the average weight of mature cows being probably under 7½ cwt. The colours are fawn, silver grey, brown and brownish-black, either whole or more or less broken with white, and with a characteristic "mealy" ring round the muzzle. The horns are small, with an inward curve, and the head is lean and refined, with the orbits very prominent. The cows are generally very "wedge-shaped" and thin-fleshed, and have an angular but refined and deer-like appearance; the skin is thin and the hair short; the udder is generally both capacious and symmetrical, and the milk veins very prominent. The quantity of milk produced is fair, perhaps good, in relation to the size of the animal. The butter-fat content is very high, averaging probably over 5 per cent. The fat globules are large and the milk is deep in colour, so that it creams rapidly and has a rich appearance. As a beef animal the Jersey is of no account.

Under favourable conditions as to climate and food the Jersey is greatly prized as a butter cow, and she is also a commercial success where there is a sufficient demand, at a special price, for a high quality of milk. The Island herd book was established in 1866 and a separate English register in 1879. Abroad the breed is numerously represented in the United States, Australia, and New Zealand.

The Guernsey (Plate VIII. A), under which name are included the cattle of Guernsey, Alderney, Sark and Herm, is a larger, less refined, and in keeping with the less favourable climatic conditions of its home, a more robust breed than the Jersey. The colours are various shades of fawn, red, yellow, and brown, the first predominating; white markings are more frequent than in the Jersey. A light or buff-coloured muzzle is preferred, but dark noses are fairly frequent. The skin is of a very deep yellow colour, and the deeper shades are preferred.

Compared with that of the Jersey, the general conforma-

A. Ayrshire Cow, "Lochdougan Princess 3rd"



["*Farmer and Stockbreeder Photograph*"

B. Jersey Cow

[" *Agricult*

A. Guernsey Cow, "Tregye Cora"

[" *Agricultural Gazette Photograph*."

B. Kerry Cow, "Minley Mistress"

tion is rougher. The shoulder is heavier and more loosely attached, the wither is thicker, and the thighs rather fleshier. A certain amount of slackness of back and a prominence at the tail head are common faults. The Guernsey is a fairly deep milker, good herds averaging perhaps 700 gallons. The butter-fat content of the milk is slightly lower than that of the Jersey—probably about 4·8 per cent. on the average—but the milk and butter are richer in colour than those of any other breed. The Guernsey grows rather longer and reaches maturity more slowly than the Jersey, which latter is often bred from at a very early age. The bulls, as is common in the case of the other small dairy breeds, are treacherous and troublesome to handle, though here again the Jersey is the more extreme type. For veal production the Guernsey calves have some little value. The steers, however, mature very slowly and are of poor quality, with an objectionably deep yellow coloured fat. Few steers are reared. The Guernsey is fairly hardy, and thrives in quite exposed situations without exceptional precautions as to shelter or food. There are both Island and English herd books. The breed has been largely exported, the United States being the principal market.

The Kerry (Plate VIII. B) and the **Dexter** are the only remaining native breeds of Ireland. The Kerry is an ancient breed, small in size, neatly built, active and hardy, standing on rather long legs and of distinctly dairy type. The colour is black, with frequently a little white on the udder of the cow. The horns are of medium length, rather thin, and curve upwards. On poor hill pastures the Kerry is a commercially useful breed, and gives a creditable yield of milk of good average quality.

The Dexter is of whole black or whole red colour, and of a distinctly dwarfish conformation, with short legs and a heavy head. The general build is compact and blocky, and the breed is a dual-purpose one. The Smithfield figures show that the breed attains rather less than 60 per cent. of the average Shorthorn weight. Crosses with Angus and other beef breeds make excellent small butcher's cattle.

The Old Gloucestershire is a breed of dairy cattle, brown in colour, with a white line extending along the middle of the loin and rump and over the tail head. It has been preserved in very small numbers, but a society was formed in 1919 with the object of reviving it. So far no very great progress can be recorded.

CHAPTER IV

BREEDING AND REARING OF CATTLE—MILK AND BEEF PRODUCTION

THE age at which heifers should first be mated depends on their breed, on their individual characteristics, and on the system of feeding and general management to which they have been subjected during the earlier part of their lives. Females of the early maturing beef breeds, such as the beef Shorthorn, are often, if they be well grown, mated at fifteen months of age, so that they calve down at two years old. Jerseys are frequently put to the bull quite as early. With breeds like the Dairy Shorthorn, which are about average in rate of growth and development, and are suited to average conditions of food and housing, the ordinary age at first service is about twenty-one months, bringing the first calf at thirty months. It is to be noted, however, that where it is desirable to arrange for the whole of the calves to be dropped at a particular season of the year, *e.g.* in pedigree beef herds, cheese dairies, etc., the choice will fall to be made as between mating at fifteen months or twenty-seven months, so that the heifer may calve in proper season either at two years or at three years old. Animals of the later maturing breeds (Galloway, Welsh, etc.) should not ordinarily calve before they are three years old, and on the poorest Highland grazings West Highlanders are sometimes not calved down till four. Heifers have been known to take the bull, and to conceive, at as early an age as four or five months, so that they must be kept apart from bull calves from this age until they are considered sufficiently developed to be served. Bulls of the earliest maturing breeds may begin to be used at ten or twelve months old; those of average development at about fifteen months. Sixty cows

may be put as a maximum allotment for a bull of two years old or over, but much depends on the length of the breeding season, *i.e.*, on whether matings are restricted to a month or two, or whether they are distributed throughout the year. Breeding bulls must be kept in active and thrifty condition by arranging for sufficient regular exercise, and by so adjusting the ration that the animal is kept in healthy condition without becoming fat.

The average period of gestation is 280 days. Œstrum generally begins to occur at from five to eight weeks after calving, so that it is possible for a cow to bear successive calves at intervals shorter than a year. The duration of œstrum is short, varying from a few hours up to one or occasionally two days, and the interval between successive periods is three weeks. Females in good condition come in "season" at all times of the year, but most regularly in spring and summer, and least regularly in late autumn and early winter. In the case of cows running out on pasture without artificial feeding, œstrum may occur only during the summer months. Unsuccessful matings are somewhat common and are due to a variety of causes.[1] Bulls are sometimes found to be sterile, either temporarily or permanently, so that if many cows fail to "hold" to their services another male should be procured.

Calf Rearing.—The first period of the calf's life, extending to perhaps six months, when under natural conditions it would be receiving its dam's milk, is one requiring somewhat special consideration. The methods of feeding and general management vary greatly according to economic conditions, such, for example, as the local value of milk and milk products, the cost of labour, the rent of the land, and the probable commercial value of the calf itself.

Veal production, as being a matter rather apart from rearing, may be dealt with first. Surplus calves of the smaller dairy breeds, such as the Ayrshire and Jersey, are frequently slaughtered for veal within a few days of birth.

[1] For a full discussion of sterility and its causes, see Hammond, *Physiology of the Dairy Cow* (Cambridge University Press, 1927).

Such animals are, however, of very little value, bringing frequently no more than a few shillings apiece, and the only reason for so disposing of them is that they are not of a type that can be either reared or fattened economically. Calves of the Friesian or Dairy Shorthorn type or, say, Ayrshire-Shorthorn crosses are, on the other hand, quite suitable for the production of good veal. The average age for marketing may be taken as six weeks, but a good product may be secured at any age from four to twelve weeks. Later the flesh takes on more or less of the character of beef, and the price obtained is less. During the short period available the animal should be kept fattening rapidly, and to this end it should be closely confined and heavily fed. In order to prevent its taking exercise it is generally placed in a small and partially darkened pen, which must be kept clean and regularly littered. Commencing with about one gallon daily of colostrum (the first milk of its dam), divided into four meals, the calf should, by the end of the first week, be receiving half a gallon thrice daily. This is still further increased, until by the end of the period the ration may be anything from two to three gallons daily, according to the animal's size. With such treatment a calf weighing 80 lb. at birth may be expected to make a steady live weight increase of 2 lb. per day, and will thus, at the end of six or seven weeks, scale about 170 lb. live weight and yield about 100 lb. of veal. The quantity of milk required to produce a pound of live weight increase, when the calf is receiving a full ration, rises from about 8 lb. at the beginning to about 12 lb. at the end, and averages perhaps a gallon (10 lb.).

When butter-fat has a high commercial value, as is usually the case, fair results may be obtained on a ration consisting, to the extent of as much as a half, of separated milk plus a cream substitute (see *infra*). Butchers, however, are generally prepared to give a higher price for calves that have received nothing but whole milk, and are often able to distinguish such from others that have been more cheaply fed. Calves used to be bled some time before slaughter in order to make

the flesh white, but the practice, which was of doubtful value, has been almost completely abandoned.

The methods of rearing that are adopted for animals destined for beef, for the dairy or for breeding, may be classified somewhat as follows: (1) The *natural* system, in which each cow suckles her own calf; (2) the *semi-natural*, where a cow suckles two or more calves during a lactation period; and (3) the *artificial*, where the calf is pail-fed, usually, in part at least, on some substitute for whole milk.

(1) The natural method of rearing ordinarily produces the best calves, and the chief ground for departing from it is that of its high cost. With deep-milking cattle, the method is of course not applicable, even when the value of the calf might justify it, because the quantity of milk produced is greater than the calf could take. The natural system is universally adopted in the better herds of pedigree beef cattle, where the value of the calf may ordinarily be expected to cover the whole cost of maintaining the cow for the year. In such herds, in fact, the bull calves, if they are intended for early sale, are sometimes transferred from their own dams to freshly calved and deep-milking nurse cows, or may be allowed to suck both. In the production of commercial beef cattle the system is almost confined to districts where cheap, rough grazing is available, and where the cows can be kept out of doors, and look after themselves, for the greater part of the year. Galloway and West Highland cows are suitable for this purpose in bleak districts, and Herefords or Sussex where the climate is less rigorous. The first two breeds will generally be crossed, if conditions permit, with the Shorthorn, in order to obtain larger and earlier maturing calves. Angus cows, kept on better land and housed in winter, are sometimes used in a like manner, and the value of the calves (for intensive feeding into "baby beef") is very high. The increased cost of maintenance of the cow is, however, a serious disadvantage.

(2) It may be reckoned that with careful treatment and suitable additional feeding, good commercial calves suitable

for early fattening can be reared on about 150 gallons of whole milk—sufficient, that is, to allow a gallon and a half daily for the first hundred days of the animal's life. It is obvious, therefore, that a reasonably deep-milking cow may be made to rear four calves in a season, and a good milker as many as five or six. Even if we allow a longer suckling period, in order to avoid some of the difficulties, and even if we aim at the production of really well-conditioned calves suitable for "baby beef," an average cow of dual-purpose type should be capable of rearing two or three annually. The essentials for the success of the system are skilled supervision, a supply of suitable calves, and the collection of a herd of cows that not only milk well but accommodate themselves to the scheme of management. Some cows, even when they are quiet to milk, will refuse to suckle other calves than their own, while others show almost complete indifference. Refractory animals should be disposed of or transferred to the dairy.

When two calves only are to be reared, close supervision is necessary only during the early stages. After the first few weeks the cow and calves may be put to grass with reasonable hope that all will go well. If, however, the cow is to have three calves during the first part of the lactation, and if these are to be weaned and replaced by others in the middle of her milking period, and the process perhaps repeated a second time, the supervision must be close and constant. Here it is generally best to keep the calves in pens or paddocks and to bring in the cows thrice a day to suckle under the eye of the herdsman.

The purchase of young calves on the open market involves the danger of introducing disease, and therefore such should be kept apart from the rest of the herd for a week or two. Again, new-born calves, if they are given to cows that are not freshly calved, must be dosed with castor oil to obtain the effect of colostrum.

When the cows are made to suckle successive batches of calves, weaning is necessarily both sudden and abnormally early, and hence every endeavour must be made to induce the calves to eat a good ration of concentrated food as the

time for weaning approaches. They should commence with a small amount of nutritious and palatable food at, say, four weeks old. A mixture of eight parts each of crushed oats (or flaked maize) and finely broken linseed cake with one part of fish meal is suitable, and the quantity should be raised, if possible, to 1½ lb. before weaning, and to perhaps 2½ lb. immediately after. In summer the calves should have a run on clean, fresh grass, or in winter should have finely-sliced roots and good hay offered, from the end of the first month.

(3) Pail-feeding has, generally speaking, the object of permitting the use of feeding materials other than whole milk. Bull calves, in pedigree dairy herds, are often fed by the pail on whole milk only, the objects being to obtain milk records of their dams and at the same time to regulate the ration ; but such a mode of feeding is not general. Separated milk, which has half the energy value and contains all the protein and ash of the natural milk, is frequently available to the farmer at a fourth of the price of the latter. Whey, which has nearly one-third of the feeding value of milk, can generally be utilised only as animal food, and can be used, with a fair measure of success, in the rearing of calves. Attempts have been made to do without milk products altogether, except in the earliest stages, but the difficulties of obtaining an easily digestible substitute with a satisfactory ash balance and a sufficient vitamine content are very great. Pail-feeding is the normal system in dairy herds and, in fact, generally where intensive farming is carried on.

Whatever substitutes are to be fed ultimately, the calf should at first receive colostrum, or, failing this, whole milk and a mild purgative. Whole-milk feeding should be continued, if at all possible, for two or three weeks, the quantity fed being increased from a gallon at first to one and a half gallons later—more or less according to the size of the calf. After that time substitution may begin, but should be gradual at first, and should extend over a further period of two or three weeks. Where separated milk is used, the additional food—the butter-fat substitute—need

supply only energy. It must be in a readily assimilable form, but apart from this it is a matter of indifference whether it consists of oil, starch, or sugar. Fats and oils, though formerly much used (*e.g.*, cod-liver oil), are generally unsatisfactory. Fed in crude liquid form they cannot be given in nearly sufficient quantity without producing serious digestive disturbance. In finely emulsified condition they are too expensive. On the Continent good results have been obtained from partially hydrolysed potato starch, but many ordinary farm foods are also quite satisfactory. Crushed linseed, ground oats, and flaked maize are all good, the two latter being preferable on account of their cheapness. The cereal meals should be used at the rate of about three-quarter lb. to each gallon of separated milk. If possible, the milk should be fed quite fresh, being separated immediately after milking and given to the calves while still warm. Skim milk, while richer in fat than the mechanically separated article, has the disadvantage of being somewhat stale. In any case it should be raised to blood temperature before being fed and should preferably not be more than twelve hours old. With separated milk and a substitute a live weight increase of 1½ lb. daily may be taken as normal.

Whey differs from separated milk in that it lacks not only the fat, but also the casein and part of the ash. Moreover, it has necessarily developed some degree of acidity. In order to stop the lactic fermentation at the earliest possible moment it should be lightly scalded as soon as it comes from the vats, such portion as is immediately required being fed warm, while that set apart for later use is thoroughly cooled and subsequently reheated to blood temperature. As a supplement in this case it is necessary to use something that is moderately rich in albuminoids. Palm kernel cake, a mixture of equal parts linseed cake meal and bean meal, and a mixture of ground oats and fish meal in the proportion of two to one have all given satisfactory results. It has, however, generally been found impossible to make up a whey ration to an energy value equivalent to that

of a full allowance of whole milk; the digestive system of the calf is not capable of dealing with so large a quantity of nutrients in the altered form. An average calf may receive 1½ to 2 gallons of whey with 1½ lb. of the substitute; half an ounce of sterilised steamed bone flour may be added in order to supply the ash deficiency. The rate of growth will generally be about half that obtained with a full ration of whole milk, or about 1 lb. per day, but the daily food cost may be reduced to about one-fourth of that of whole milk feeding.

Weaning, which may occur at any age between three and six months, should be carried out in stages in order that the calf may gradually become accustomed to ordinary foods. These should be given in ample quantity and of good quality, as the check sustained may otherwise be severe. The following is an example of a winter ration for a Shorthorn calf of six months old weighing 3 cwt. and intended for beef at two years old. Such an animal kept in good growing condition should make a live weight increase of rather more than 1¼ lb. per day. Requirements may be calculated as follows:—

1. Dry matter consumption at 2½ per cent. of live weight = 8·4 lb.
2. Energy requirement—
   (*a*) Maintenance, $6 \times \left(\frac{336}{1000}\right)^{\frac{2}{3}}$ = 2·94 lb. S. E.
   (*b*) Production, 1·3 lb. live weight increase at 1¾ lb. S.E. per lb. = 2·28 „
   Total energy requirement . 5·22
3. Protein requirement—
   (*a*) Maintenance, $0{\cdot}6 \times \frac{336}{1000}$ = 0·20 lb. P. E.
   (*b*) Production, 1·3 lb. live weight increase at 0·4 lb. P.E. per lb. = 0·52 „
   Total protein requirement = 0·72

	Composition per cent.			In Ration.		
	Dry Matter.	Starch Equivalent.	Protein Equivalent.	Dry Matter.	Starch Equivalent.	Protein Equivalent.
0 lb. Swedes .	11·5	7·0	0·7	2·30	1·40	0·14
3 lb. Meadow hay	85·7	31·0	4·6	2·57	0·93	0·14
1½ lb. Oats . .	86·7	60·0	7·6	1·30	0·90	0·11
1½ lb. Maize meal	87·0	81·0	6·8	1·30	1·21	0·10
1 lb. Palm kernel cake . .	89·0	75·0	17·0	0·89	0·75	0·17
¾ lb. White fish meal . .	87·0	53·0	48·0	0·22	0·13	0·12
Totals				8·58	5·32	0·78

In summer, calves after the age of six months will do well on ordinary grass with the addition of perhaps 2 lb. of any of the less fibrous concentrates. Cotton cake should not be used till the animal is older.

The general scheme of feeding varies according to the purpose for which the particular animal is being reared. If intended to be fattened at an early age it must have a liberal ration with preferably a fair quantity of whole milk in the early stages. Weaning should be late, and should be carried out by easy stages, in order that the "calf flesh" may not be lost. At the other extreme, a heifer calf intended for the dairy is purposely kept rather lean, the belief being that otherwise it would develop an undesirable tendency to fatten, and might probably fail to reach its full milking capacity.

As regards housing and general management, young calves should be housed, either singly or in small lots, in well-ventilated but not draughty pens, which should be floored with concrete and swept out daily. They will frequently eat their litter if this be not prevented, and the consumption of straw or peat moss has sometimes fatal results. They should therefore be muzzled for the first three or four weeks, a precaution that also prevents their sucking each other about the navel. In summer, they should run on fresh and clean grass, and shade during hot weather

is a great advantage; but in many districts it is found best to keep the younger animals indoors during their first summer. This applies to such as have not been weaned at the beginning of the grazing season. Males should be castrated at about four weeks old.

When the period immediately following weaning has been successfully passed, the feeding and management become simple. In summer, young cattle do well on ordinary pasture without artificial feeding, the only exception being in the case of animals that are intended to be marketed fat at an early age—say, before they are two years old. The latter should have an allowance of 2 to 4 lb. of concentrate, unless the pasture is more than ordinarily good. Yearling cattle will require from half an acre to an acre or more of pasture each, according to its quality. In winter, growing cattle may be tied up in byres, or run in covered courts or partially open yards. In districts where the winter is mild, *e.g.* the south-west of England and south-west of Ireland, those of eighteen months or more do best out of doors, on pasture. Store animals will thrive when closely confined, but young animals that are being intensively fed must have exercise. The open court, or failing this, a covered court with a daily run on pasture, is preferable even in the case of stores, as the animals grow better coats and are much less liable to suffer a set-back when they come to be turned out in spring. The following are examples of winter rations.

(1) For a twelve months' old store bullock weighing 5 cwt., in an arable district:—

Swedes	40 lb.
Oat straw	8 „
Palm kernel cake	3 „

This supplies about 14 lb. of dry matter (equal to $2\frac{1}{2}$ per cent. of the live weight), 6·4 lb. starch equivalent, and 0·76 lb. protein equivalent. Maintenance requirements are 4 lb. starch equivalent and 0·35 lb. protein equivalent, and the surplus, viz., 2·4 lb. starch equivalent and 0·42 lb. protein equivalent, is sufficient for slightly over 1 lb. live weight increase per day.

(2) For a two year old store bullock of 8 cwt., intended for early summer fattening, in a grass land district:—

Meadow hay	20 lb.
Oats	2 „
Maize germ cake	2 „

This supplies 21 lb. dry matter, 9 lb. starch equivalent, and 1·24 lb. protein equivalent. Maintenance requirements are 5·5 lb. starch equivalent and 0·54 lb. protein equivalent, so that the balance available for production would be 3·5 lb. starch equivalent and 0·7 lb. protein equivalent, sufficient for fully 1½ lb. live weight increase. In actual practice the full ration of hay would only be given for a short period, say from January till March, the quantity being regulated during the remainder of the winter according to the state of the grazing.

Milk Production.

The first essential to any economical system of milk production is a herd of deep-milking cows. It is true that the actual yields, as well as the profits, depend very largely on the skill of the dairyman in feeding and general management; but no management, howsoever perfect, can prove successful if the cattle have a low limit of production. Hence everything possible must be done to secure good foundation stock, and, by careful selection and mating, to maintain or improve the average yield. To this end a system of milk recording is essential. Individual cows, under what may be termed ordinary farm conditions, vary in yield from 200 or 300 gallons to 1000 or 1200 gallons, and accordingly may leave a large profit or a very considerable loss. The average yield of the world's dairy cows is probably not over 400 gallons, whereas good herds, with a standard of management that is quite attainable under strictly commercial conditions, may reach 800, or occasionally more. The composition of the milk varies too with the breed and with the individual; in particular the percentage of butter-fat, which is the most valuable constituent, may be anything from three to six, without counting very abnormal individuals. There is no

adequate evidence as to the hereditary factors that determine production, nor of the mode of their transmission; but we know, in a general way, that milking qualities are inherited, and hence milk records, apart from their value as a measure of the economy of production of individual cows, are of the utmost importance in breeding.

An actual record must always be considered in relation to the conditions under which it is made. Obviously, the size of the cow must be taken into account. The economy of milk production, as has previously been pointed out, depends essentially on the ratio between the production ration and the maintenance ration; the latter varies, not in direct proportion to the live weight, but with the two-thirds power of the live weight. Thus, for example, a 12-cwt. cow will require 30 per cent. more for maintenance than an 8-cwt. animal, and hence it may be calculated that 800 gallons from the latter would be as profitable a yield as 1040 gallons from the former. Clearly, too, a record must be considered in relation to the general system of feeding. An insufficient ration will limit the production and prevent the animal from giving any true account of herself.

Again, age has a well-known influence on yield. From the fourth lactation onwards the cow may be considered as mature, and little increase in yield occurs after this time. Naturally, the yield declines ultimately, but the age at which the decline sets in may vary from eight years to perhaps twelve. A heifer calving for the first time at thirty months old may be expected, in her first lactation, to produce about 70 per cent. of her mature yield, and with her second and third calves about 85 per cent. and 90 to 95 per cent. respectively. The butter-fat content of the milk varies but very little with age.

The normal lactation may be taken as lasting about ten and a half months. The cow should have at least six weeks' and preferably eight weeks' rest before calving, and should be in calf again three months after freshening. An abnormally long period of rest previous to calving has the effect of increasing the yield during the subsequent lactation

and delay in mating has the effect of permitting a longer continued flow. In any case, the milk produced after the expiry of twelve months should not be counted towards the record. A long period of rest, particularly if the cow be fattened, may have the further result of increasing the butter-fat content of the milk during the first few weeks of the subsequent lactation.

Finally, the season of calving has an important influence on the yield. The change from winter to summer feeding generally stimulates the flow, whereas the reverse change in autumn has the opposite effect. This effect is greatest if the change occurs at the time when the yield is beginning to decline, say at two to four months after freshening. It has been found that a cow calving in December may yield quite 30 per cent. more than another of equal real capacity calving in August; but, obviously, no generalisation can be true for all conditions, and the more skilful the winter feeding the less will be the effect of season of calving.

Many attempts have been made to estimate milking capacity on the basis of short tests—of, say, seven days' duration. It has been shown that with cattle that are fed and managed in the ordinary way, there is actually a very high correlation (about 0·85) between the maximum daily yield, at, say, six or eight weeks after calving, and the total yield in a normal lactation. The relationship is, on the average, such that if the maximum daily yield of a winter calving cow is multiplied by 200, there is obtained a very fair approximation to the normal lactation yield. For summer calving cows the factor would be about 185. Thus, an average cow, producing, say, 3 gallons a day at her best, might be expected, if she calved in winter, to reach 600 gallons in a normal lactation. Since, however, the correlation is not absolute, the rule is not strictly applicable to the poorer milkers or those that are much above the average. The difference from the average should be multiplied by 0·85, the co-efficient of correlation, and the product again multiplied by the lactation factor. Thus, if we assume that 600 gallons is an average yield, a 5-gallon

cow, calving in winter, should produce in a lactation: $(3 \times 200) + (2 \times 0{\cdot}85 \times 200) = 940$ gallons. Similarly a winter calving cow, yielding 2 gallons at the top of her flow, might be expected to produce $(3 \times 200) - (1 \times {\cdot}85 \times 200)$ or 430 gallons in a normal lactation.

Short period tests, in spite of their inherent value, are of very little use in practice. The difficulty is that it is possible, by special feeding, to stimulate the flow for a short period, as well as temporarily to raise the butter-fat content. Even yearly records are open to objection in cases where the cattle are carefully rested and prepared, or where mating is delayed beyond the normal time. The average production over a series of three or four years is by much the best measure of value.

Milk records, if they are to receive general recognition, must obviously be vouched by an independent authority. In some systems the milk is weighed and tested at regular intervals by inspectors, but such are open to the objection that it is possible so to treat the animals as to obtain an abnormally high yield on particular days. The better system is to make the owner responsible for weighing and recording the yield at each milking, and to have the milking inspected, the weights checked, and the milk tested for butter-fat content by inspectors making surprise visits.

Feeding for Milk.

The feeding of dairy cattle, if maximum production is to be made possible and waste prevented, is necessarily a somewhat complicated business. Sufficient energy, protein, ash, and vitamin must be supplied to meet the maintenance requirement and to provide for the full quantity of milk that the cow is capable of yielding. The maintenance requirement is 0·6 lb. of protein equivalent and 6 lb. starch equivalent per 1000 lb. live weight. A gallon of average milk contains 0·35 lb. of protein, so that the protein requirement, per gallon of milk produced, cannot be under this figure. It seems likely that if we could always feed such a mixture

of proteins as would supply the correct proportions of the various amino acids, etc., that go to form the casein and lactalbumen of the milk, the requirement of digestible protein would actually be at the rate of little more than 0·35 lb. per gallon of milk produced. But in practice it will always be necessary to allow a margin, and the accepted standard is now 0·6 lb. protein equivalent per gallon of average milk.

The total energy value of a gallon of average milk (3·7 per cent. butter-fat) is about 3200 cals. If, therefore, we were to take Kellner's value for the pound of starch equivalent—viz., 1071 cals. of net energy—it would be necessary to feed 3 lb. ($\frac{3200}{1071}$) of starch equivalent for each gallon of milk produced. The value of 1071 cals. of net energy per pound of starch applies, however, to fattening oxen, and it has been shown that the milking cow is distinctly more efficient as an energy transformer than the fattening steer. The probable explanation of this fact is that the cow has a direct outlet in her milk for protein and carbohydrate, and is not under the necessity, as is the fattening animal, of transforming its whole surplus energy into the form of fat. The difference in efficiency is considerable, amounting to fully 25 per cent. Expressed differently, the pound of starch equivalent yields 1360 cals. in the form of milk as against 1071 cals. in the form of body fat. The quantity of starch equivalent required per gallon of milk of average composition is thus $\frac{3200}{1360}$, or 2·35 lb. approximately. The energy requirement per gallon will of course depend on the composition of the milk, notably on its fat content. The following table (page 458) embodies the recommendations of the recent Departmental Committee on Rationing of Dairy Cows.

In the case of the cow giving milk of average composition, and where ordinary cakes and meals are to be used as the production ration, the quantity required will be about $3\frac{1}{2}$ lb. per gallon. This implies a starch equivalent of 71 and a protein equivalent of 17 per cent. Such a ration will contain fully 3 lb. of dry matter. As is pointed out in the chapter on nutrition, the cow's food capacity generally lies

between $2\frac{1}{2}$ and 3 lb. of dry matter per hundred pounds live weight per day. 3 lb. of dry matter per hundredweight (112 lb.) is a good general figure. Hence if we are dealing with cows of 11 cwt. live weight, with yields running up to 5 gallons, maintenance requirements must be met by a

Production Standards (per 10 lb.) in respect of Milk of Varying Qualities.

Fat content of milk (per cent.).	Starch equivalent.	Protein equivalent.
	Lb.	Lb.
3·7 to 3·8	2·50	0·60
3·9 „ 4·0	2·60	0·63
4·2 „ 4·3	2·75	0·67
4·45 „ 4·55	2·87	0·70
4·7 „ 4·8	3·00	0·74
5·2 „ 5·3	3·25	0·81

ration containing not more than 18 lb. of dry matter (33 lb. total minus 15 required for production). The following are examples of rations supplying the necessary minima of energy and protein (6·9 lb. starch equivalent and 0·73 lb. protein equivalent) for maintenance in not more than the bulk indicated :—

(*a*) 20 lb. good hay (medium hay is generally given a starch equivalent of 31, very good hay one of 40. A starch equivalent of 35 would meet the case).
(*b*) 40 lb. swedes or mangels with 14 lb. medium hay.
(*c*) 30 lb. tare-and-oat silage with 10 lb. medium hay.
(*d*) 60 lb. swedes, 6 lb. oat straw, 6 lb. medium hay.

The first is suitable for grassland farms, the second and third for mixed farms ; the fourth can be successfully used only in districts where the roots and straw are known to be of at least average quality. In many districts they fall short, in nutritive value, of the figures given in the tables. In areas where the roots and straw are exceptionally nutritious, *e.g.* in the North-East of Scotland, excellent maintenance rations can be made of these alone.

As regards the production ration, this should ordinarily consist of a mixture of three or four distinct materials in order that the proteins may approach maximum efficiency. The following are suitable standard mixtures to be fed at the rate of $3\frac{1}{2}$ lb. per gallon :—

(*a*) Two parts maize meal, 2 parts bean meal, 2 parts palm kernel cake, 1 part decorticated earth-nut cake.

(*b*) Two parts maize gluten feed, 1 part rice meal, 1 part barley meal, 1 part linseed cake, 1 part decorticated cotton cake.

(*c*) One part coconut cake, 1 part decorticated earth-nut cake, 1 part linseed cake, 2 parts palm kernel cake, 2 parts rice meal, 1 part maize gluten feed.[1]

In the choice of concentrates, apart from questions of price, due regard should be paid to the type of maintenance ration. If this is costive in tendency the production ration should be laxative and *vice versâ*. Coconut cake and linseed cake are mildly laxative.

It will be clear that a scheme based on maintenance and production rations such as those indicated above does not meet the case of heavy milkers, viz., of cows of average size giving more than 5 gallons per day. While the proportion of cows that actually give 5 gallons or over on winter feeding is small, there is no doubt that many more are inherently capable of doing so. A very partial solution of the difficulty is to increase the concentration of the production ration in such degree that 3 lb. will provide the necessary nutrients for 1 gallon. This implies a starch equivalent of 83 and a protein equivalent of 20 per cent. Such a mixture might be composed for example, of equal parts flaked maize, palm kernel cake, bean meal, coconut cake, decorticated earth-nut cake, and crushed linseed. But a more satisfactory method is to reduce the bulk of the maintenance ration by substituting concentrates for hay. It has been found that the coarse fodder can be reduced to

[1] Boutflour's standard mixture.

6 or 7 lb. without harm to the health of the cow. In theory the hay so withdrawn should be replaced by concentrate, at the rate of 1 lb. of the ordinary production mixture for $2\frac{1}{2}$ lb. of hay; but in practice Boutflour has found that the additional concentrate need not be fed. This is probably explained by the fact that the ordinary production ration contains a slight surplus of nutrients, which in the case of a 7- or 8-gallon ration adds up to a considerable total. A 9-gallon cow, weighing 11 cwt., would thus receive $31\frac{1}{2}$ lb. of concentrate and 7 lb. hay, making 33 lb. of dry matter in all. Such rations have actually been fed with successful results.

The object of rationing according to yield is, of course, to ensure the maximum yield of milk of which the cow is capable, while enabling her to maintain herself in good thriving condition. Cases of individual cows becoming too fat or too lean do frequently occur in rationed herds, generally because due regard is not paid to variation in the composition of the milk. In such cases the ration should be altered at discretion.

An important point in dairy cow management is that the cow should be brought into fit bodily condition and accustomed to a fairly substantial ration of concentrates before she calves. This process may commence (with 3 or 4 lb. of cake) six weeks before the calving date, and the ration may be raised to 8 or 10 lb. for the last fortnight. A mild purgative should be given when it appears that parturition is imminent. Only a light ration should be fed for the first few days after calving; but thereafter the concentrate should be rapidly increased day by day until it exceeds, by 2 or 3 lb., the amount corresponding to the actual yield. Excess should continue to be fed so long as the yield shows a tendency to rise.

The mineral content of the ration requires special consideration in certain cases. The moderate milker receiving a full maintenance ration will normally get enough mineral matter, at least if the bulky foods have been produced on land that contains sufficient lime and phosphates. The

heavy milker on the other hand will receive a large proportion of her food in the form of cakes and meals, most of which are deficient in minerals. The addition to the production ration of 1 or 1½ per cent. of a mineral mixture will be desirable in such cases. Two parts powdered chalk, 2 parts common salt, and 1 part sterilised steamed bone flour form a mixture which has given satisfactory results. Blocks of mixed minerals, which are obtainable commercially, may as an alternative be fixed in the mangers, and the cattle allowed to lick them at will. The composition of the milk is in the main independent of the feeding. Some materials such as maize gluten feed, coconut cake, and earth-nut cake have a slight, and sometimes only temporary, effect in the direction of increasing the butter-fat content. On the other hand there is some evidence that rice meal and perhaps other foods of high oil content have a depressing effect on the fat content. The matter is, however, not fully understood. In any case a high oil content in the ration is undesirable, and it should not exceed 5 or 6 per cent. The character of the butter-fat is markedly influenced by feeding—linseed cake, for example, produces a soft oily butter, while bean meal, cotton cake and palm kernel cake produce a firm fat.

Regarding the arrangement of the ration, concentrate may suitably be given just before milking. Roots or silage, which are liable to taint the milk, should be given not less than three or four hours before milking; long fodder, which is liable to contaminate the air with dust, should be fed soon after milking. The following is an example of a suitable arrangement of the diet:—

5.45 A.M.	One-third concentrate.
6 to 7.15 A.M.	Milking.
7.15 A.M.	Half root ration.
9 A.M.	Half long fodder.
11 A.M.	One-third concentrate.
2 P.M.	Half root ration.
5.45 P.M.	One-third concentrate.
6 to 7.15 P.M.	Milking.
7.15 P.M.	Half long fodder.

On the question of the preparation of the food it may be taken as a good general rule that roots should be fed either whole or roughly sliced, coarse fodder in the long state, and the concentrate in dry form. Moreover, each of these elements in the ration should be fed separately. The extensive use of chaffed fodder is undesirable, and the mixing of concentrate with chaffed fodder and pulped roots is still more so. For production purposes a mixture of cake (in nut form) with meal is better than meal alone. The feeding of wet mash is common in certain districts, but it is a method of very doubtful economy.

A supply of pure drinking water is necessary for cattle in milk, unless the ration contains both an excessive quantity of roots and a considerable amount of water in the form of mash. The normal consumption of a cow yielding 2 gallons of milk per day, fed on a dry ration, and in ordinarily cool weather, may be put at 10 gallons daily. Heavy milkers, in hot weather, have been observed to consume up to 25 gallons. The most satisfactory method of supplying water, when the cattle are indoors, is by means of automatic drinking bowls. Failing these, water should be offered thrice daily, the last drink being given as late in the evening as possible.

In summer, if cattle are on fairly good fresh pasture, it will generally suffice to give $3\frac{1}{2}$ lb. of concentrate for each gallon of milk produced above two; or, in case the pasture is of the better class and during the earlier part of the season, for each gallon above three. When pastures get bare much additional food may require to be given, such as cut green forage, mangels in early summer, or cabbages later, hay and additional concentrate. Even if grass is abundant its feeding value generally declines from August onwards, and during October it will do little more than provide for maintenance. Deep-milking cows must have their grazing restricted in the latter part of the season, otherwise they may consume too much of the bulky and innutritious herbage. An average cow requires from about $1\frac{1}{4}$ to 2 acres of pasture, according to its quality when this is managed

on the ordinary system, or half to three-quarters of an acre under the intensive system of management.

Where soiling is practised the full ration of green forage will be from 60 to 80 lb., according to its feeding value and the size of the cow, with the usual allowance of concentrate.

It is worth noting that many summer foods, such as clover, vetches, and ordinary pasture grass, are much richer in protein than most home-grown winter foods, such as roots and straws. Hence the concentrate fed in summer may frequently be so made up as to have an albuminoid ratio of the order of about 1 : 5 or 6, and yet give fully satisfactory results. This may permit the use of a mixture of, say, sharps, maize-meal, and palm kernel cake, which will often be appreciably cheaper than the type of mixture described on p. 459.

In all cases feeding should be at strictly regular hours. The cattle should be quietly handled, should be groomed daily during winter, and should have some little exercise, except during severe or inclement weather. A majority, however, will thrive perfectly even if kept continuously tied up. The hoofs will require occasional dressing to prevent their growing too long.

Cow sheds should have ample air space; local authorities generally prescribe 600 cubic ft. per cow, or 800 if the cattle are continuously indoors. Much more important than the actual cubic space are efficient ventilation, good lighting and drainage, and facility for cleaning. The floor should be of non-absorbent material, such as concrete, except, perhaps, the front part of the stall, which may be of rammed clay or chalk, in order to prevent injury to the cows' knees. The size of the stalls must be adapted to that of the cows; for moderately small breeds, such as the Ayrshire, the double stall should be about 6 ft. 6 in. wide and about 5 ft. 3 in. long, exclusive of the width of the trough. For average shorthorns an extra 6 in. each way will be necessary. If yokes are used instead of chains the stalls should be made 6 in. shorter, as the cows in yokes stand farther forward.

Too much width or length is just as unsatisfactory as too little. In the first case a cow is liable to turn partly round in the stall, and to tread on her neighbour, as well as to soil the litter. A suitable general arrangement of a cow house, with dimensions, is shown in Fig. 58.

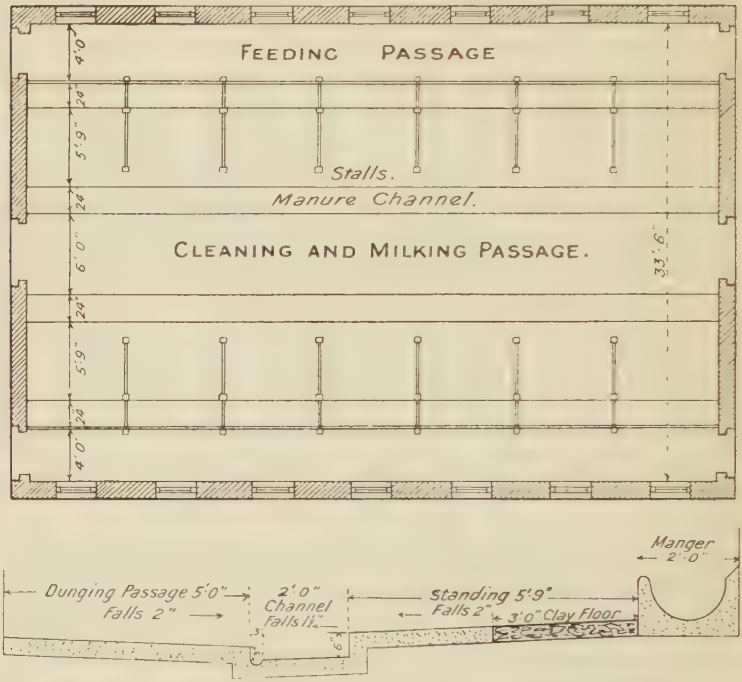


FIG. 58.—(*Upper*) Plan of Double Shed for 28 cows. Dimensions are for cows of average size. Stalls are 7 feet wide.
(*Lower*) Section of floor of single shed to show levels.

The atmosphere of the byre should be kept cool and fresh. It has been shown that there is no gain in milk from restricting ventilating so as to maintain the temperature above 45 or 50° F., which temperature is quite consistent with free ventilation even in the coldest weather ordinarily experienced in Britain. At the cooler temperature the cattle are much less liable to chills, and are more weather-

hardy when they come to be turned out in spring. The cattle should be kept littered with clean straw, and the byre floor should, if possible, be washed as well as swept daily. The lower part of the walls, which should be faced with concrete, should frequently be brushed down with water.

If this be done the following precautions will ensure a clean product:—

(1) The hindquarters of the cows should be kept closely clipped and the animals should be groomed daily; the udder and teats should be rubbed over with a clean moist cloth, and dried with a clean dry cloth before milking. Grooming must not be done immediately before milking as this causes contamination by dust during milking. The first "draw" of milk from each teat should be rejected.

(2) The atmosphere of the cowshed should be kept free from dust. Dust may come in from outdoors or may be produced by handling long fodder or litter before milking. As it is impossible to exclude bacteria from the atmosphere altogether, a hooded pail should be used in order that a minimum surface of milk may be exposed. Milk should be removed from the cowshed as each cow is milked.

(3) Personal cleanliness should be required of the milkers and washing facilities should be provided. Wet milking should be forbidden.

(4) All utensils, such as milking pails etc., should be thoroughly cleansed and sterilised before milking begins.

(5) The milk should be passed through a suitable strainer and immediately cooled, in a clean atmosphere, to as low a temperature as possible.

(6) Careful watch should be maintained over the health of the cattle, and the milk of any unhealthy animal should be excluded from the general supply. It may, after scalding, be fed to pigs.

It will be obvious that these general rules may be interpreted in various ways. Where the milk is sold as "ordinary" milk, the price obtained will rarely be sufficient to compensate the producer for the installation of elaborate sterilising and refrigerating plant, or for all the labour that is required to ensure the minimum of contamination. On the other hand where the highest class of Graded Milk is aimed at, no detail can be neglected.

Milking need not be done more than twice a day, except in cases of heavy milkers. A change from three milkings to two will generally produce a diminution of the yield, but the 3- or 4-gallon cow soon adapts herself to the new routine. The intervals between milking should be as nearly equal as possible, because otherwise the butter-fat content of the milk, after the longer period, will always be low. With milkings at 4 A.M., 10 A.M., and 3 P.M., a somewhat common type of arrangement in fresh-milk dairies near towns, it has been shown that the morning milk may be quite 0·5 per cent. lower in butter-fat than the average of the three milkings, and hence may sometimes fall below the British presumptive standard of 3 per cent. Milking should be done quickly and thoroughly, as not only is the last-drawn milk or "strippings" by far the richest in fat, but also because the leaving of even a small quantity in the udder leads to a rapid diminution of the yield. A good milker may be expected to milk from seven to ten average cows in an hour and a half, the time ordinarily allotted for the work. Ten cows is a usual allotment to each person, though if the animals all freshen at one season of the year, extra help may be necessary for a month or two. Milking machines of the latest types give very satisfactory results, with skilled supervision and with thorough hand "stripping."

Cows that are still milking at six weeks before their next calving time should then be put dry. It will often suffice merely to stop milking, when secretion will cease and the milk will be resorbed. Sometimes partial withdrawal of the milk is necessary, but this should be avoided unless the animal is in pain.

Beef Production.

The type of animal best suited to the production of beef has been sufficiently described in the last chapter. There can be no question that the breeder should aim at the best possible beef type. But the feeder, if he is nothing but a feeder, may find that the finest commercial type of store commands a more or less fancy price, and that he can obtain a larger profit from a somewhat rougher animal that can be bought cheaper. Really poor, ill-bred, and thin-fleshed animals will rarely leave a profit either to the breeder or the feeder. The most economical age for fattening depends on the development of early maturing qualities in the particular animal. It is obvious that all cattle should be marketed at the earliest possible age, consistent with making the most of their capacity for growth and bringing them to a usefully fat condition. On the other hand, it is useless to attempt to force the pace with *e.g.* West Highlanders or Galloways. Angus, Herefords, and Shorthorns of beef type, if they are well fed as calves, and if they are carried on without a "store" period, can be marketed either as "baby beef" at fifteen to eighteen months or as young beef at eighteen to twenty-four months. This system is well adapted to the better sort of mixed farms where breeding and feeding are combined. On the other hand, feeders who buy in stores and who work on a system of rapid turnover prefer cattle of some age because they fatten more quickly. Two and a half years is still probably about the average age for cattle to be put up to feed, and some of the later-maturing breeds are kept till they are three years old or over. Old and heavy cattle, however, sell at a considerable discount as compared with young, well-finished animals.

The general scheme of feeding must be adapted to the prevailing economic conditions. If the fattening process is likely, in itself, to be a profitable operation—*i.e.*, if there is any considerable margin between the value per pound of lean and fat animals, and if feeding stuffs are cheap—the general rule will apply that the more rapid the process of

fattening the higher will be the profit. Obviously, if one animal is fattened in four months and another, on a lighter ration, to the same degree in six, the latter is debited with the cost of an additional two months' maintenance, without any compensating advantage. In the past half-century, however, the conditions stipulated have rarely existed, and the fattening of cattle has come to be regarded as essentially a means for the disposal and conversion into manure of the bulky and non-marketable by-products of the arable or mixed farm. Hence it is often good policy to feed a maximum of such by-products, and to confine the use of purchased concentrates to the barest minimum. Generally some such concentrates will be necessary if the animal is to obtain sufficient nutrients to enable it to make reasonable progress, and also, very frequently, to correct the protein deficiency of roots and straw.

As regards winter feeding, the ration will depend mainly on the particular home-grown feeding stuffs that are available. On arable farms the chief constituents will generally be roots and straw. Seeds hay is generally more profitably used for other purposes than for cattle feeding; but a limited amount is very useful in the last stages of the fattening process, when the animal's appetite for the coarser fodders tends to decline. Silage is a valuable substitute for roots in districts where roots cannot be regularly grown with success. Good silage, made from any of the ordinary mixtures of, say, oats, beans, peas, and vetches, has nearly twice the energy value, weight for weight, of swedes, and more than twice the protein equivalent, so that expensive highly nitrogenous concentrates become unnecessary. On the other hand its fibre content is considerably higher, so that its use leads to a reduction in the amount of straw, etc., that the animal will consume. In semi-arable districts meadow-hay will generally be available in quantity, and in pastoral regions it will form the basis of the ration. In the colder and later arable districts where grain is often of poor market quality, oats and barley are frequently used.

During the progress of fattening, as the animal's appetite

for bulky food declines, the concentrated ration must be increased. Kellner's standard for a fattening steer allows 13½ lb. of starch equivalent and 1½ lb. of digestible protein per 1000 lb. live weight. On such a ration a 1000-lb. animal should add about 2½ lb. daily to its live weight, more in the earlier stages when the live weight increase consists partly of water and protein, less in the latter when the gain is chiefly fat. Only really good cattle will make such an average increase, if they are to be kept until they are really prime beef. 2 or 2¼ lb. per day must be considered a satisfactory gain. In practice, as has just been indicated, it may often be wise to rest content with a daily increase of 1½ to 2 lb., using a less nutritious ration. In countries where cheap concentrates are available (*e.g.* maize in the corn belts of North and South America), rations with as high a starch equivalent as 18 or 20 lb. are sometimes fed, and the gain may reach 3 or even 3½ lb. per day for short fattening periods. Such rations are often imperfectly digested, and pigs must be kept with the cattle to consume the residue.

The following are examples of winter rations for arable and semi-arable conditions, and for the beginning, middle, and end of the fattening period respectively. The cattle are assumed to weigh 8½ cwt. at the beginning, and to make an average live weight increase of 2 lb. per day over a feeding period of five months. The fat weight would thus be about 11 cwt.

Arable Conditions.

Beginning.		Middle.		End.	
Turnips . .	100 lb.	Swedes . .	84 lb.	Swedes . .	70 lb.
Oat straw . .	14 ,,	Oat straw . .	12 ,,	Oat straw . .	6 ,,
Palm kernel cake	5 ,,	Palm kernel cake	2 ,,	Seeds hay . .	6 ,,
		Linseed cake .	2 ,,	Linseed cake .	4 ,,
		Maize meal . .	2 ,,	Maize meal .	4 ,,
Dry matter .	25 lb.	Dry matter .	25 lb.	Dry matter .	25 lb.
Starch equivalent	11 ,,	Starch equivalent	12·5 ,,	Starch equivalent	13·5 ,,
Protein equivalent	1·4 ,,	Protein equivalent	1·6 ,,	Protein equivalent	2·0 ,,

Semi-Arable Conditions.

Beginning.		Middle.		End.	
Turnips	42 lb.	Swedes	42 lb.	Mangolds	42 lb.
Oat straw	6 ,,	Meadow hay	16 ,,	Meadow hay	14 ,,
Meadow hay	14 ,,	Barley meal	4 ,,	Barley meal	5 ,,
Barley meal	3 ,,	Palm kernel cake	3 ,,	Linseed cake	4 ,,
Palm kernel cake	2 ,,				
Dry matter	25 lb.	Dry matter	25 lb.	Dry matter	25 lb.
Starch equivalent	11 ,,	Starch equivalent	13 ,,	Starch equivalent	13·5 ,,
Protein equivalent	1·4 ,,	Protein equivalent	1·7 ,,	Protein equivalent	2·0 ,,

"Baby beeves," *i.e.*, such as are being fed while still in rapid growth, require a more concentrated type of ration. Straw cannot be successfully used and even hay must be limited so that no more than a third of the dry matter is supplied in this form. In all cases, the choice of particular concentrates should be determined by ruling market prices.

Apart from questions of bulk, energy value, and protein content, the palatableness of the ration may require special consideration. Some feeding stuffs, such as palm kernel cake, are not readily eaten at first but are consumed freely enough when the animals have had a week or two to become accustomed to them. An occasional animal will refuse any and every sort of cake. Sprinkling with molasses water, or admixture with any of the commercial condiments, will often be helpful. Again, stores from grassland districts take some time to learn to break roots, and an occasional animal gives up the problem altogether. Such should be transferred, if possible, to individual boxes and given a special ration. Regarding the preparation of the food generally, roots must be sliced for cattle that are in process of changing the first pair of incisor teeth (say eighteen to twenty-four months old). Otherwise it is doubtful whether any special preparation of the food is profitable. Many experienced feeders give the roots whole, the fodder long, and the cake in the ordinary form of nuts or squares. On the other hand some feeders chaff a proportion of the fodder, slice the roots, and mix the two together, with or without the addition of meal. This

doubtless decreases the work of mastication, but it involves a large amount of additional labour, and there is no satisfactory evidence that the advantage is sufficient to leave a profit. Only if straw is not being consumed in the quantity desired, owing, for example, to its tough and dry condition, it may be chaffed and either mixed with pulped roots or moistened, and left for a day to ferment slightly before being fed. The concentrate should not be added to the mixture in such cases, as the fermentation causes loss of nutrients without any compensating advantage. Heavy root rations are always liable to cause scouring, particularly early in autumn; materials like soya bean cake and linseed cake, which have also a laxative tendency, should not be fed with them; undecorticated cotton cake, on the other hand, is an excellent corrective.

The particular details in the arrangement of the ration are of less consequence than strict adherence to whatever scheme is adopted. In practice straw is generally given *ad libitum*, and the racks are filled morning and evening, or oftener if necessary. The roots should be given in two feeds, or if the ration is over 80 lb., in three; the concentrate should also be given in two meals if the amount exceeds 4 or 5 lb. Many feeders believe in allowing a period of two hours of entire quietness in the middle of the day. Cattle receiving 80 lb. of roots or over will not as a rule drink water, but if the root allowance is less, and, in fact, generally towards spring, as the temperature rises and the water content of the roots decreases, water should be offered.

Regarding housing, fatting cattle may be kept in single or double boxes, or may be run in lots of up to twelve or twenty in covered or partially open yards; or, again, they may be tied up in stalls, as dairy cows are (a common practice in the north). Single boxes doubtless give the best results, but the method is expensive, both in labour and in housing space. Stalls are economical of space, 50 sq. feet being sufficient floor space for a beast against nearly 100 in covered courts. Stalls are likewise economical of litter, 7 lb.

being a sufficient daily allowance, while about twice this amount is needed in yards. The labour is, however, increased as compared with other methods owing to the necessity of individual feeding, daily removal of manure, and occasional grooming. The conservation of the manure will be less satisfactory than where it is kept firmly tramped in yards. Partially open courts are wasteful of litter and manure, but are otherwise satisfactory except in very exposed situations. Cattle running together in lots are always liable to disturbance from restless or pugnacious individuals, and occasional beasts are prevented from getting their share of food. Lots usually settle down best if they have been grazed together for a month or two before being housed. In any case horned cattle should have the tips of the horns removed before they are housed in lots, otherwise there is endless disturbance and a consequent loss of weight. A limited amount of stall or box accommodation is always necessary, in order that bullying or frightened or sickly animals may be segregated.

Summer fatting of cattle may be carried out on the best sort of permanent grass without additional feeding, the land carrying a full-sized bullock to the acre, and providing some autumn and winter grazing for stores in addition. First year's rotation grass on good arable land will often do as well as this. Of average feeding pasture 1¼ to 1½ acres will be allowed per head, and some concentrate will be given at least during the latter part of the season. The concentrate used should be one of high energy value and low protein equivalent. Maize germ meal, maize meal, barley meal, and rice meal, made up for convenience in cube form, give satisfactory results. Cattle may be fed on the soiling system in the same manner as dairy cows.

The degree of fatness to which cattle should be brought before marketing depends on market conditions. It must be realised that during the last stage of feeding—that which makes the difference between "good" and "prime" condition—the live weight increase is obtained at a very high cost. On the other hand, when prime cattle are scarce, the extra cost may be more than repaid in the increased value per

hundredweight. Ordinarily fat cattle will dress about 57 per cent. of their live weight, or, say, 8 lb. to the stone. Prime cattle will reach 62 or 63 per cent., and exceptional animals in very high condition from 65 to 70. Very lean animals may yield under 50 per cent. of carcass. The largest items in the "sinkage" are the contents of the alimentary canal (15 per cent.) and the hide (7 per cent.). Dressing percentage will obviously vary considerably with the quantity of food contained in the stomach and intestines; cattle fasted and thirsty may weigh 70 or 80 lb. less than when full.

CHAPTER V

SHEEP AND GOATS

SHEEP and goats, with certain intermediate species, are generally regarded as forming one group of the Cavicornia or hollow-horned ruminants.

The true sheep comprise a considerable number of wild species which fall into two rather distinct natural groups. The one includes the Mouflon (*Ovis musimon*) of Corsica and Sardinia together with the closely related species of Cyprus (*O. cypria*) and of Asia Minor (*O. orientalis*); and the Urial (*O. vignei*) of Persia, Northern India and Tibet. The other group consists of the Argali (*O. ammon*) of Western Siberia and the Altai; Marco Polo's sheep (*O. Poli*); and the Bighorn of Northern Siberia (*O. nivicola*) and of the Rockies (*O. montana*). The true goats include the Markhor (*Capra falconeri*) of Afghanistan, and the common wild goat or Bezoar (*C. ægagrus*) of the Caucasus, Persia, and Crete. The Steinbock and the Tur are included in the genus *Capra*, while the Bharal or Blue Sheep of Tibet, the Barbary Sheep, and the Tahr of Nepal and Kashmir, represent types intermediate between sheep and goats and are referred to separate genera.

Nothing is known for certain regarding the origin of domesticated sheep. The view most widely held is that the Asiatic Mouflon supplied most of foundation stock, but the Urial and even the Argali have sometimes been regarded as the ancestors of some domesticated types. The older view, to the effect that the wild ancestor must have been quite different from any surviving species, is not now accepted. The common goat is descended from the Bezoar, and the Cashmere goat from the Markhor, while the valuable Angora

is generally believed to have been derived from a cross between the two.

Sheep are valued commercially for their mutton and wool and occasionally also for milk. With some breeds, such as the Merino, wool is the primary product, while British breeds are kept mainly for mutton, wool being a secondary, if still an important, consideration. The points of the mutton sheep correspond rather closely to those of the beef ox, the valuable qualities being a tendency to fatten early in life (early maturity), a thick covering of lean meat and an even and not wasteful distribution of the fat. The head varies greatly with the breed, but should be of good depth and width, strong of jaw, and broad through the nose; the neck moderately short, and thick at its junction with the body; the body deep, wide, and square; the shoulder top wide, level, and well covered; the chest deep and wide, and the ribs well sprung or rounded. The shoulder neatly laid and thickly covered, and the region behind the shoulder well filled up; the hind-quarters long, broad, and level, with the width well carried out to the rump; the gigot or leg of mutton thickly fleshed, and the flesh well carried down, both inside and out; the back should be wide and level throughout, thickly covered with firm muscular flesh; the legs moderately short and well set apart, the bone neither too coarse nor too fine, but clean and hard. The thickness of the tail is a useful measure of condition or fatness. The carriage should be stylish and springy, indicating activity and robust health.

Sheep's wool is commercially by much the most important fibre of its kind, although other wools and hairs, for example, mohair, cashmere, alpaca and camel's hair are all used as textiles. Wool is used in the manufacture of a great variety of articles. The chief are, of course, articles of clothing for the inhabitants of the colder regions of the world, but carpets, tapestries, and blankets absorb a considerable quantity of certain classes. The characteristics of the wool fibre on which its value mainly depends are as follows:—

1. *Length.*—This varies from under an inch to over two

feet, the coarser wools being generally the longer. Other things being equal, the longer wools are the more valuable.

2. *Uniformity in Length of the Different Fibres in the Staple.*—This is important, because, for certain purposes, the short fibres require to be separated and put to a different use, bringing a lower price.

3. *Strength and Elasticity.*—Strong, elastic fibres suffer a minimum of breakage in the process of manufacture and naturally give a stronger yarn. Fine fibres are generally relatively stronger than coarse. The staple should be free from any weak part or "break," as wool with such a "break" cannot be combed without great wastage. The condition is generally due to the sheep having suffered a severe check during the period of growth of the wool.

4. *Fineness.*—The mean diameter of the fibres may vary from about $\frac{1}{1500}$ of an inch in the finer merino wools to $\frac{1}{600}$ or more in the coarser long-wool fleeces. The smaller the individual fibres the finer the yarn that can be spun from them, and in yarns of the same weight the finer wool gives a softer and fuller character, which in turn gives the finished cloth a better appearance and "handle." Softness is due chiefly, but not entirely, to fineness of the individual fibres.

5. *Felting Qualities.*—The aptitude of the different fibres to interlock depends on the fineness and extent of the waviness or "crimp." Fine merino will often show more than twenty waves to the inch, while most longwools give only three or four. Crimp also gives springiness or elasticity to the finished cloth. Felting further depends on the number of epidermal scales, and on the extent to which their upper edges project. Fibres with a smooth surface like those of the Lincoln or Wensleydale sheep, are naturally slippery. On the contrary, Merino or Down wool (which has the appearance under the microscope of a series of irregular flowerpots set one inside the other) felts readily.

6. *Colour.*—A clean white wool can be dyed to any desired shade, whereas coloured wools, or those containing a proportion of black or brown fibres, have a restricted use. Hence dark fibres are objectionable and every endeavour

should be made by the breeder to eliminate them by selection. Certain natural-coloured wools, *e.g.* brown or "moorit" Shetland, have a higher value, for special purposes, than white wools.

7. *Lustre.*—Wools with large, flat, epidermal scales have a bright shiny appearance, whereas if the scales are small and the surface rough the wool is dull in appearance. High lustre and felting qualities are obviously incompatible.

8. *Behaviour to Dyes.*—True wool absorbs dye differently from what is called kemp, which is a coarse and generally brittle fibre with a characteristic dead-white appearance. It does not absorb dye in the ordinary dyeing process, and hence causes unsightly marks in the cloth. Here, again, the breeder should make every effort to get rid of the fault by careful selection of his breeding sheep. Kemp is commonest in the wool of mountain sheep, and generally increases with age.

9. *Uniformity of the Different Portions of the Fleece.*—Previous to its manufacture, wool is sorted into lots of similar length, fineness, etc. Sometimes, as in the best merino wools, the fleece is practically uniform throughout. In most sheep the quality varies according to the part of the body from which the wool is taken. That from the shoulder is generally the most valuable, being deep in staple, uniform, and fine. The neck wool is often finer, but is much less uniform; that from the breech, on the other hand, is both coarse and irregular. The wool-sorter divides the fleece into different "counts," the count representing the number of hanks of yarn (each 560 yards long, according to the Bradford system) that could be spun from a pound. The count, as usually applied, is a measure of fineness, although in actual spinning the length of yarn that can be got from the pound of wool varies with the length as well as with the diameter of the fibres. A good average merino fleece might give wool of 64 quality from the back part and 70's from the front. A typical Longwool (*e.g.* Lincoln) fleece sorted into its separate counts is shown in Fig. 59. Skirtings, cots, brand marks, and soiled locks are removed before or during the process of sorting.

Wool is manufactured by either of two methods. In the worsted process the raw material, after scouring, is combed so that the short fibres are removed. The latter are sold as "noil" to the woollen manufacturer, while the long fibres, arranged parallel to each other in a sort of rope, form "wool

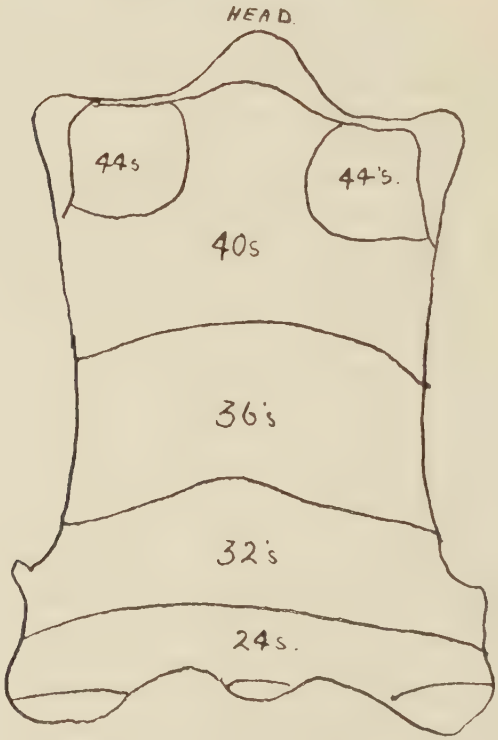


FIG. 59.—A Longwool Fleece, showing Sortings. (After Jones.)

tops." The tops are spun into a rather firm, hard thread, the cloth made from which has a distinct thread structure and a bright appearance. The important qualities in worsted wools are length, strength, uniformity, trueness, elasticity, lustre, and fineness. High-felting qualities are generally not required. In the woollen process the short fibres are not removed, length being unnecessary. The material is

carded, that is, it is teased out into a thin web in which the fibres run in all directions. The carded "sliver" or rope is condensed and spun without further treatment. The cloth is more or less felted by moisture and pressure, so that the fibres are interlocked in all directions, and the thread structure becomes indistinct. The important qualities for this purpose are fineness, softness, and felting properties. A break in the staple is an unimportant defect, and lustre is not wanted since the haphazard arrangement of the fibres would, in any case, conceal any natural lustre of the wool.

The value of natural or "greasy" wool will of course vary with the proportion of fatty and sweaty matter that it contains, as well as with its moisture content. The "yield" of scoured wool, after the removal of the "yolk," may be as high as 80 or 85 per cent. in the Longwools, and may fall to 60 or even as low as 30 per cent. in some Merinos. Vegetable impurities, such, for example, as straw, burrs, grass seeds, or fibres, *e.g.* from jute packs or hemp string, are all very objectionable in wool, since they do not absorb dyes in the same manner. They are often difficult to separate, and their presence in large quantities may render it necessary for the wool to be carbonised (treated with acid and heat) in order to destroy them. Hence every endeavour should be made to keep them out. Clipping should be done on a clean-swept floor, and in no case should any material but wool be used as string or packing. From the farmer's point of view the weight of the fleece is obviously an important consideration. This depends on the size of the sheep and on the length and density of the fleece. Single fleeces of modern breeds vary from 2 or 3 up to 15 lb., and exceptionally up to 30 or 40 lb.

The wool breeds of sheep, as distinct from those in which mutton is the prime consideration, are all derived from the Merino of Spain. The Spanish sheep is now of little account, but its descendants have covered a great proportion of the globe and many distinct types have been evolved, notably in Australia, the United States, Germany, and France. Of these the American "*C*" type and Delaine Merino as well

as the French Rambouillet are relatively large, robust, smooth-bodied sheep, of fair mutton conformation, and with wool of good length (3 in.) and moderately fine quality. At the other extreme is the American "*A*" type, small and of very poor mutton form, with a very wrinkled skin, and a heavy clip of very fine but short and very greasy wool. Merinos are best adapted to dry and at least moderately warm climates, and are a profitable type of stock for land at a great distance from centres of population.

British Breeds.

Neglecting a few of minor importance, there are thirty-two British breeds of sheep, falling into three main groups:—

(*A*) **Longwools**, embracing the Leicester, Border Leicester, Wensleydale, Lincoln, Cotswold, Devon Longwool, South Devon, Kent or Romney Marsh, and Roscommon. These are, broadly speaking, the largest breeds. They are white-faced (except the Wensleydale), hornless, and have a fleece of long lustre wool. They mature fairly early and fatten readily, but the mutton, at least of the older animals, tends to be coarse-grained and poor in flavour, and readily becomes too fat.

(*B*) **Shortwools**, including six breeds that are ordinarily spoken of as Downs, and seven others. The Downs are hornless, with dark faces and legs, and generally a short, close fleece of relatively fine quality. The mutton is generally of very good quality, with a high proportion of lean meat and of fine flavour. Originally associated with the Chalk Downs, they have now spread all over Britain, except the mountains, and are kept under a great variety of conditions. The Down breeds are the Southdown, Shropshire, Suffolk, Hampshire Down, Dorset Down, and Oxford Down. The Oxford is not a typical member of the group but is intermediate between the Down and Longwool types. The remaining short-wooled breeds are the Dorset Horn and Western or Wiltshire Horn (white-faced horned), the Ryeland and Devon Closewool (white-faced hornless), the Kerry

Hill (speckled-faced hornless), and the Clun Forest (dark-faced, hornless).

(*C*) **Mountain Breeds.**—These have little in common except their generally small size, good quality of mutton, and their ability to live on mountain or moorland grazings. They include the Scotch Blackface, the Swaledale, the Lonk and the Rough Fell Sheep, all belonging to the dark-faced, coarse-wooled, horned type. The Derbyshire Gritstone is sometimes grouped with these, but is softer wooled and hornless. The others are the Cheviot, Welsh Mountain, Herdwick, Exmoor Horn, Dartmoor, and Shetland.

The Leicester (Plate IX. A) is the oldest, or at least was the earliest improved of the Longwool breeds. It was evolved by Bakewell between 1755 and 1790 from the pre-existing Old Leicester type. The latter was large and coarse, late maturing, and of poor mutton type, though it bore a good fleece of long combing wool, and was hardy and prolific. Bakewell effected an enormous improvement in early maturity and in mutton qualities generally, but it is generally acknowledged that he allowed the fleece to deteriorate and the fecundity to decline. Bakewell's type would doubtless carry far too much fat for modern taste, but fat meat was at his time in demand. During and after Bakewell's time the Dishley Leicesters spread all over the country; they gave rise, as an offshot, to the Border Leicester, and they were used in the improvement of all the other Longwools and of some other breeds as well. With the change of taste in favour of smaller and leaner mutton, the breed declined towards the end of last century; but during the last thirty years it has become popular again and has been improved anew, particularly in length of fleece, quality of flesh, and fecundity.

The modern Leicester is a medium-sized longwool, of low-set and blocky conformation. The head is wedge-shaped, the nose slightly Roman and rather thin at the bridge; the hair on the face white with a bluish tinge and dark spots, and the lips and nostrils dark. The forehead is covered with wool, the ears are bluish or white, long and

thin; the neck is short and thick, and is carried almost horizontally. The fleece is fairly dense, of good length, and is fine, curly, and highly lustrous. Good ewe flocks will clip about 10 lb. per head. The mutton is of fair average Longwool quality.

The chief centre of the breed is now East Yorks and Durham. Many flocks, especially on the Yorkshire wolds, are kept for ordinary commercial purposes, while others are maintained in order to produce rams for mating with Mountain or more generally with "Masham" (Wensleydale × Blackface Mountain) ewes. Abroad, the breed has been successful in Australia, New Zealand, and Tasmania, and to a less extent in South America. It is also found in Canada and the United States, but there it has been merged to some extent with the Border Leicester.

The Border Leicester (Plate IX. B) is descended from Dishley sheep that were brought to the Scottish Border district well over a century ago. Whether or not any Cheviot blood was introduced in the formation of the Border type has been much disputed. English Leicester rams continued to be imported by Border breeders until about 1850, but since that time the types have been kept distinct. By 1869 they had so far diverged that the Highland Society decided to institute separate classes for the two types.

This breed is of similar weight to its relative, but is higher on the leg and lighter in the offal. The head is long, rather thin through the nose and light behind the ears. The nose is aquiline, the whole head free from wool, and the lips and nostrils black. The ears are large, white with occasional black spots, and carried rather high. The neck is distinctly long, but thick at its junction with the trunk, and the head is carried gaily and high. The breed is exceptionally wide and level of back, and is very easily fattened. The wool is in separate locks or "pirls" of about finger size, but not open to the skin. It is wavy, lustrous, and of good length; 10 lb. is reached as an average clip in the best flocks, and 14 lb. is a common clip for well-bred ram hoggs. The Border Leicester is fairly hardy and very prolific. Flocks

A. English Leicester Ram

B. Border Leicester Ewe

A. Half-bred Shearling Ram [*Brown & Co., Lanark*

B. Wensleydale Ram

kept under good conditions will produce 170 per cent. of lambs or more, and the ewes are good milkers. The chief use of the breed is the production of rams for crossing with Cheviot and Blackface Mountain ewes. It is admirably adapted for mating with the smaller and leaner breeds owing to its combination of size, early maturity, and a thin head, which last is an important feature in connection with parturition. Border Leicesters are largely bred in Northumberland and Cumberland and throughout all the lowland districts of Scotland, and the breed is common in Northern Ireland. The eastern border district around Kelso is still its centre. The Border Leicester has been largely exported, and is probably, next to the Lincoln, the most widely known of the Longwools. It gives excellent results when crossed with the Merino.

Half-Bred (Plate X. A) or Border Leicester × Cheviot ewes are the common type of breeding ewes on arable farms north of Yorkshire, and are an important commercial type in many grassland districts in the Midlands and elsewhere in England. They are hardy, very prolific (rarely giving less than 150 per cent. of lambs), and excellent mothers, and when crossed again with either Oxford, Suffolk, or other Down rams, produce an excellent type of butcher's sheep.

The Wensleydale (Plate X. B) was produced originally by crossing the Dishley Leicester with an old, large, white-faced breed known as the Teeswater "Mug." The characteristic blue face and legs were derived from the half-bred Leicester ram "Bluecap," born in 1839.

The Wensleydale is a large-framed sheep, rather long of leg and long of body. The depth of rib is good, but the back is less broad than that of the Leicester. The head is strong, highly carried on rather a long neck, and the forehead carries a tuft of wool. The fleece is long, and is finer and silkier, and carries a higher lustre than that of any other Longwool. It is divided into locks of about pencil size, and is open in character. Good ewe flocks average up to 9 lb. of wool. The face and legs are of a very characteristic deep blue colour.

The Wensleydale is probably the hardiest of the Longwools, but is notably narrower in build than the Leicester or Lincoln and is distinctly later maturing. The mutton is of good quality with, for a Longwool, a remarkably high proportion of lean meat. The breed is mainly found in the North and West Riding of Yorkshire, and in Lancashire. Its chief use is the production of rams for crossing with the various black-faced mountain breeds, both in the north of England and in the south-west of Scotland, where it competes with the Border Leicester. The first crosses are known in Yorkshire as "Mashams," and in Scotland as "Yorkshire Crosses." Masham ewes are often mated back to Wensleydales in the lower country, producing "twice-crossed" lambs. Both sorts are very useful commercial sheep for winter feeding.

The Lincoln (Plate XI. A)—Before the era of live-stock improvement there existed in Lincolnshire a large, coarse breed of sheep, with a remarkably good fleece of long, strong, lustrous combing wool. For long the breeders of old Lincoln sheep held out against the introduction of Dishley Leicester blood, but eventually crosses were made, and the modern Lincoln undoubtedly owes something to the outside blood, which, although it temporarily diminished the size of the sheep and the length of wool, improved the fattening qualities and symmetry.

The Lincoln is the largest British breed. Mature rams in show condition occasionally reach 400 lb. live weight, and the average weight of the wethers (at twenty-two months old) shown at Smithfield in recent years has been practically 3 cwt. The Smithfield weights show the breed to be about 12 per cent. heavier than the Leicester. Compared with the English Leicester, the Lincoln is more massively built and has a rather longer and stronger head which is generally carried a little higher. The ears are always more or less dotted with black. The wool is of great length, that of hoggs frequently reaching 18 in.; it is very dense on the pelt, wavy, lustrous, and strong, but distinctly coarser than that of the Leicester. The locks are as broad as two fingers, and are

less completely separated than in the Leicester. The clip is heavy; 11 or 12 lb. is not an uncommon average in good flocks, while ewe hoggs often give a stone and ram hoggs as much as two stones of wool. In the show type a good deal of wool is carried on the hind legs below the hocks, and there is a top-knot of long locks.

The Lincoln is quite hardy, commercial flocks being found at considerable elevations in the east midlands; but it requires fairly abundant food. It is not remarkable for fecundity, 130 per cent. of lambs being considered a satisfactory crop. The quality of the mutton, at least of the older sheep, is generally poor. In Britain the breed has not spread far beyond its native county, most of the leading flocks being found in Lincolnshire and south-east Yorks. Abroad, however, especially in Australia and Argentina, it is in great favour on account of its value for crossing with the Merino. The cross-bred is large and readily fattened, and yields a heavy fleece of useful medium-quality wool. The well-known Corriedale breed, originally formed in New Zealand but now widely distributed throughout the world, was produced by fixing the characters of this cross.

The Cotswold has existed from very early times in the range of hills whose name it bears. Leicester blood was used in its improvement, but no crossing has been done for nearly a century. Hardly inferior in size of frame to the Lincoln, the Cotswold is somewhat higher on the leg and less massive in build. The back is broad and the quarters long and wide, with the rump sometimes too prominent. The head is rather long and fine, with a top-knot of long wool hanging well down over the eyes, and is carried high on a neck of good length. The fleece is long and fairly dense and the clip heavy, frequently reaching an average weight of 10 lb. The fibre is coarser and straighter than in the foregoing breeds, but is of good lustre. The face and legs are either white or mixed with light grey; the nostrils are black. The breed is, for a Longwool, very hardy, and thrives well on poor, dry, upland farms. The mutton is of second-rate quality, but

crosses, *e.g.* with the Hampshire, are good, and even the pure bred is satisfactory if killed at an early age. In Britain the Cotswold is confined to its somewhat narrow native district, and even there has suffered from the competition of smaller and earlier maturing breeds. Abroad it has found a considerable market in the United States.

The South Devon (Plate XI. B) is a large, robust type of sheep found in Cornwall and South Devon. In many respects it resembles the Lincoln, but is longer in body and, on the average, less squarely and massively built. The wool is dense, long and curly, but coarser than in the Lincoln, particularly at the breech. The mutton is of good quality, with a high proportion of lean meat.

The Devon Longwool is smaller than the last (roughly equal to the Leicester in size), but somewhat irregular both as to size and type. The fleece is finer and more silky than in the South Devon. The quality of mutton is good. The Devon is the predominant Longwool breed in North and East Devon and Somerset.

The Kent or Romney Marsh (Plate XII. A) is an old breed native to the rich but cold, exposed and damp grassland district from which it is named. Like all Longwools the modern breed is indebted to some extent to the Leicester, but it has retained many of its original characteristics, and is in many ways the most distinct of the Longwool breeds. Of these it is the smallest, the mean weight being perhaps 5 per cent. less than that of the Leicester. It is low of leg, stout-limbed, and long-bodied. Often it is low at the shoulder and deficient in heart girth in proportion to its development of hind-quarter. The forehead is very wide and generally carries some short wool; the nostrils are black. The wool is denser than that of any other Longwool and is much finer in quality, though shorter and less lustrous, and sometimes rather coarse at the breech. The fleece is heavy, ordinary commercial flocks yielding an average of 7 lb. or thereby, and pedigree flocks reaching over 8 lb. The Romney is hardy, does well on grass without hand-feeding, and is relatively immune from such diseases as foot-rot and

[*J. T. Newman, Berkhampstead*

A. Lincoln Long-wool Ram

[*"Agricultural Gazette Photograph"*

B. South Devon Shearling Ram

A. Kent or Romney Marsh Shearling Ram

["*Agricultural Gazette Photograph*"

B. Southdown Shearling Ewes

liver-fluke that so frequently affect sheep on wet land. The sheep graze singly, rarely flocking of their own will. The breed is not notably prolific, giving perhaps 120 per cent. of lambs under ordinary conditions.

The Kent has spread to some extent in the south-eastern counties of England, and rams are used for crossing with Down ewes. Abroad it is very popular, notably in the North Island of New Zealand, but also in Australia, South America, and to a less extent in the United States and South Africa.

The Roscommon is the only surviving breed of sheep that is native to Ireland. It is a large breed, as tall as the Lincoln or Cotswold, but probably on the average inferior in weight to the former, although very high individual weights are recorded. The wool is close and broad in the staple, of rather fine quality and fair length. The breed is somewhat late maturing, but the ewes are hardy, prolific, and good mothers, and the mutton is well mixed and generally of good quality.

The Southdown (Plate XII. B) was the earliest improved of the Shortwool type, and was used in the improvement or formation of all the modern Downs, just as was the Dishley Leicester in the production of the modern Longwool breeds. The Southdown has existed for several centuries on the chalk hills of Sussex, and the old type, before the improvers had set to work, was described as a small, dark-faced and occasionally horned breed, long in the neck, light in the fore-quarter, long and narrow in the back, with a light, thin fleece. The hind-quarter was, however, well developed, and the gigot thickly fleshed. The first of the great improvers was John Ellman of Glynde, near Lewes, who started farming about 1780 and bred Southdowns with great success for fifty years. He avoided close in-breeding and, unlike Bakewell, he devoted close attention to the fleece and to the breeding qualities. Also he increased rather than diminished the size of his breed. Ellman's chief successor in the work of improvement was Jonas Webb, of Babraham, Cambridge, who began about 1821.

He improved the size and early maturing qualities, while maintaining the original good qualities of the breed.

The Southdown is distinctly the smallest of the Down breeds and attains, at maturity, less than two-thirds of the weight of the Lincoln. Full-grown rams of the better sort, in fat condition, weigh about 200 lb., and good ewes in breeding condition about 130 lb. The general build is very neat, compact, and symmetrical. The head is very wide, and short from the eyes down, of an even mouse colour and wooled over the forehead, but not round the eyes or over the bridge of the nose. The ears are covered with short wool. The leg of mutton is remarkably thick and heavy. The wool is short (about 2 in.), dense, and very fine, commanding the top price per pound for British wools. The clip in good ewe flocks may reach 5 lb., or occasionally more. For quality of meat the breed is unsurpassed, and as a winner of carcass competitions it occupies a place comparable to that of the Aberdeen-Angus among cattle, and the Berkshire among pigs. The lambs mature and fatten very early and produce small fleshy joints with very little bone.

The breed is reasonably hardy, but below the average of the Down type in prolificness. The rams are largely used for crossing, with a great variety of breeds, for the production of fat lambs. Pure-bred flocks are fairly widely distributed throughout south-eastern England, and the breed has been exported in large numbers to most sheep countries. Its small size and comparatively light fleece are, however, against its wide use for crossing with the Merino type of ewe.

The Shropshire (Plate XIII. A) originated before 1850 in Shropshire and Staffordshire. It was produced from local sheep by crossing with the Southdown, and possibly, in earlier times and to a less extent, with the improved Leicester. Of these local types the two most important were those of Morfe Common, near Bridgenorth, and of Cannock Chase in Staffordshire. The new breed first attracted attention at the Royal Show in 1853, and in 1859 it was definitely recognised by being given separate classes. Although the type has

changed considerably since those times, no further outside blood has been introduced.

In size the Shropshire stands about half-way between the Southdown, which is the smallest, and the Oxford, which is the largest of the Down breeds. The head is wide above, short, and wooled right down to the nose. The face and legs are of a soft black colour, sometimes a little mixed with grey. The general form is square and blocky, on short strong legs that are wooled almost down to the feet. The fleece is dense, of good length (fully 3 in.), and of typical Down quality. In good flocks the average clip will reach 8 lb. The wool is relatively free from dark fibres, though some are generally to be found about the head and legs. The Shropshire is very early maturing, and hence excellent for fat lamb production. The quality of mutton is good, but the carcass lacks something of the smoothness of that of the Southdown, and can easily be made too fat. The fertility is high, 150 to 160 per cent. of lambs being common. The breed is fairly hardy, adapts itself well to a great variety of conditions, and the rams are very useful for crossing with the leaner and later maturing types of ewe. In Britain it is still most numerous in Shropshire and the adjoining counties, but there are scattered flocks throughout other English counties, and in Scotland. Abroad it is the most widely distributed and the most generally popular of its class, and in the United States it is easily the most numerously represented of all the mutton breeds.

The Suffolk (Plate XIII. B.) was formed in the first half of the nineteenth century by crossing the old black-faced Norfolk Horned breed with the Southdown. The former had existed in East Anglia from early times, and was a very active, hardy, and prolific breed producing a light fleece and a very lean carcass. By 1850 the new type had been fairly well fixed, and by 1859 it was recognised locally as a definite breed. In 1886 separate classes were provided for it, for the first time, at the Royal Show.

Though slightly inferior in weight to the Oxford, the Suffolk is one of the larger of the Down breeds. The head

is rather long, generally quite free from wool, and, with the legs, of an intense glossy black colour. The neck is rather long, the bone stout, and the legs free from wool. The fleece is of fair length and density, and of typical Down quality. A good average clip would be 7 lb., but some choice flocks reach 9 lb. Dark fibres in the wool are rather common, and the lambs are black or parti-coloured when born. The mutton is full of lean meat and of very high quality. In carcass competitions in Britain the Suffolk competes strongly with the Southdown and the Mountain breeds. The breed has a high reputation for prolificness, giving frequently over 150 per cent. of lambs, and for ability to thrive on poor land. The lambs are, however, slower in fattening than those of the Shropshire.

In Britain large numbers of rams are used for crossing with Longwool ewes, the crosses being so good that they form a favourite type for exhibition at fat stock shows. In the north they are the popular breed for crossing with the younger ages of half-breds, and are sometimes used on Cheviot draft ewes. The centre of the breed is still East Anglia, but there are many flocks in other districts of England and in Scotland. South and East Africa and Chile have been the principal foreign markets.

The Hampshire Down (Plate XIV. A) owes its origin to the crossing of Southdowns with two old local types, the dark-faced, horned, Berkshire Knot, and the Wiltshire, a white-faced, horned, and very light wooled sheep that is still in existence. The breed was formed in the first half of the nineteenth century, and was first recognised by the Royal Agricultural Society in 1861.

According to the Smithfield weights the Hampshire is rather inferior in size to the Suffolk, but the ordinary specimens of the breed are probably of equal size. It is massively built, with strong bone and a rather large head, wide between the ears, and often with a Roman nose. The wool on the head reaches below the level of, and generally surrounds the eye. The shoulder top is generally very wide and the gigot well developed. The wool reaches about 3 in.

[*G. H. Parsons, Alsager*

A. Shropshire Shearling Ram

B. Suffolk Down Ram Lamb

A. Hampshire Down Shearling Ram

B. Oxford Down Shearling Ram

in length, is of nearly as good quality as Shropshire, but only moderately dense, and with dark fibres rather frequent. A good average clip would be 6 lb. The face and legs are of a deep rich brownish black.

Hampshires are very rapid growers, lambs reaching great weights. They do not fatten quite so readily as Shropshires, nor do they produce so fine a quality of carcass as the Southdown. The breed is well adapted for folding on arable land, and is the favourite on the mixed Down and arable holdings on the chalk formation, where the ewes generally lamb in January, and many of the lambs are sold fat in spring. The ewes breed earlier in the year than those of other breeds, excepting the Dorset Horn. The Hampshire is not very prolific, a lambing percentage of 120 being regarded as good. In many flocks a large fall of lambs is not specially desired, as twins cannot easily be got ready for the early (Easter) lamb market. The heavy head and wide shoulder have prevented the breed being used, like the Suffolk, for crossing with the smaller sort of ewes, but it crosses well with the Longwools. Abroad the Hampshire has met with a considerable measure of success in many sheep countries, but in none is it a first favourite.

The Dorset or West Country Down was formed by mating Southdown rams with Hampshire ewes, and by crossing the product with the native western Down type. It may be described as generally similar to the Hampshire; it is, however, smaller, being about equal in weight to the Shropshire; also it shows more refinement in the head and bone, and has a distinctly lighter coloured face and legs.

The Oxford Down (Plate XIV. B) is another breed that owes its origin in part to the Hampshire, having been formed between 1830 and 1850 by crossing that breed with the Cotswold. Some Southdown blood was also introduced. Crossing of Downs and Longwools is often done in commercial flocks, but the Oxford is the only case in which the cross-bred type has been successfully fixed. The breed was first granted separate classification at the Royal Show in 1862.

The Oxford is the largest and heaviest of the Downs. In some respects it most nearly resembles the Shropshire, but apart from the difference in size, the Oxford has a much longer and less dense fleece, and much less wool on the head and legs. There is a top-knot of long wool, and the face colour is uniform dark greyish brown, lighter than in the Shropshire. The head, too, is longer, and the ears longer and thinner. The clip is heavy, reaching an average of 9 lb. in the better flocks. The wool is coarser than that of the other Downs. The Longwool blood shows up, too, in the carcass. As lambs or young tegs, Oxfords give meat of good quality, but at a greater age, say towards a year, the carcass tends to become fat and coarse, and the size of the sheep passes beyond the desirable limit. Oxford rams are very suitable for mating with the older ages of half-bred ewes, as Suffolks are for the younger, and the Oxford cross is the most numerously represented on arable farms in the north. The breed is widespread throughout Britain, with its centre in Oxfordshire and Gloucestershire. Abroad it has proved successful in most districts where food is plentiful.

The Dorset Horn (Plate XV. A) is an ancient breed native to Dorset and the adjoining parts of Somerset, Wiltshire, and Hampshire, including the Isle of Wight. The breed is of medium size with white face and legs, and is horned in both sexes. The nose is pink or flesh-coloured, never black as in the Longwools. It is about similar in weight to the Shropshire, but is longer in body and generally more loosely built, with a lighter fore-quarter and a somewhat narrower back. The wool is as fine as that of any of the Downs, excepting only the Southdown, of fair density but of only moderate length. It is clear white in colour when scoured, and is free from dark fibres, whereas that of most Downs is creamy white, and often contains black or brown; 5 lb. is reckoned a good average clip. The quality of the mutton is good, but the carcass usually lacks the thickness of flesh of that of the typical Down. The breed is hardy, and specially well suited to poor and dry semi-upland pastures.

The ewes are very prolific and excellent milkers. Their most striking peculiarity is that they will often take the ram as early as April or May, so that small fat lambs may be had from them by Christmas. Formerly they were very widely used for the production of house lamb, but the extensive importation of frozen lamb from New Zealand (Canterbury lamb) has almost put an end to the business. A proportion of Dorset ewes will breed twice a year, but no satisfactory or permanent system of this kind has ever been found possible. The ewes cross well with Down rams, especially Shropshires, giving excellent lambs for early fattening. The breed has been rather extensively exported to North America and Australasia.

The Western or Wiltshire Horned Sheep is an old breed that at one time was nearly extinct but has recently been revived. A considerable number of small flocks are to be found in Northamptonshire and Buckingham. The Western is a sheep of good size, somewhat resembling the Dorset Horn but of rougher conformation. The skin is often spotted with black, and the breed is peculiar in that it produces practically no wool. Such fleece as it possesses generally falls off in spring. The breed is hardy, and thrives well on grass throughout the year. The rams are used, especially in North Wales, for crossing, the cross-bred lambs being quick growers and coming early to market.

The Ryeland (Plate XV. B) is descended from a very small and very fine-wooled breed that was common in the West Midlands during the eighteenth century and probably much earlier. In most districts this type seems to have been bred out of existence by repeated crossing with Leicesters, but in the poor and sandy tract in South Hereford (Ryelands) many of the original qualities were retained, along with something of the size and fattening qualities of the Dishley sheep. The Ryeland is still a small breed, only a little heavier than the Southdown. The face is of a dull white colour with dark nose, and is wooled down to the eyes. The general symmetry is good and the sheep is well covered with firm flesh. The wool is of good quality, not so fine as

Southdown, but deeper in the staple and of a clear white colour. Good flocks give an average clip of about 6 lb. The carcass is blocky and thickly fleshed, but with rather more fat than that of the Downs. The rate of growth of the lambs is only fair. The Ryeland is not exceptionally prolific, but thrives on cold, damp, and inferior land with a minimum of hand feeding. It is kept entirely as a grass-land breed, *i.e.*, it is rarely folded on arable crops. The home of the breed is still the southern part of the Welsh Border area, but pure-bred flocks are maintained in many parts of England. At one time the Ryeland seemed to stand in danger of being ousted by the Shropshire, which is its neighbour on the north side, but the past twenty years have seen a marked increase in its popularity and numbers.

The Kerry Hill (Wales) occupies a position intermediate between that of the Down and that of the true mountain breeds. Geographically, and to some extent as regards its descent, it is midway between the Shropshire and the Welsh Mountain. Its home is the Kerry Hills district of Montgomeryshire. In size it approaches the Shropshire. The face and legs are speckled black and white, and there is a tuft of wool on the forehead. The wool is of Shropshire type, but generally somewhat coarse on the breech, as in many mountain breeds. The ewes are very prolific and good nurses. The quality of the mutton is good. The Kerry ram is often used for crossing with Welsh Mountain ewes, and again the Kerry ewe is often crossed with the Shropshire for the production of fat lambs. Some exportations have been made, but the breed has not yet become generally known abroad. The Breed Society dates only from 1899, although the breed has existed in very much its present form for nearly fifty years.

The Devon Closewool is native to the area lying between Barnstaple, South Molton and Blackmore Gate in North Devon. It is derived from crosses between the Devon Longwool and the Exmoor Horn. Some of the flocks date from the end of the nineteenth century; but it was not until 1923 that a Breed Society was formed. Intermediate

["*Agricultural Gazette Photograph*"

A. Dorset Horn Shearling Ram

[*J. T. Norman, Berkhampstead*

B. Ryeland Shearling Ram

A. Blackface Shearling Ram

["*Agricultural Gazette Photograph*"

B. Swaledale Ram

in size between the two parent breeds, and hornless, the Closewool otherwise approaches more nearly to the Exmoor Horn, being compact in build, thickly fleshed, and carrying a heavy and dense fleece of useful medium quality wool. The Closewool is a hardy breed, admirably suited to "Down" or semi-upland conditions, and living on grass for the greater part of the year. It is growing in popularity and in numbers.

The Clun Forest is an old local breed found in the Clun district of Shropshire. It is related to the Kerry Hill but carries more Shropshire blood. The breed is dark faced, hornless, of medium size, and like the Kerry Hill is notably hardy and prolific.

Mountain Breeds.—The blackfaced mountain type seems to have been first known in the Pennine Chain, and all the modern varieties of it appear to have a common origin in this district.

Of these **the Scotch Blackface** is now the best known and most definite and uniform in its characteristics. It must have reached the Southern Uplands of Scotland several centuries ago, but was not introduced into the Highlands till about 1750. Previous to this time the Highland grazings were stocked mainly with cattle, and what few sheep there were belonged to the old Celtic soft-wooled type, which is still to be met with on some of the Western Isles. The Scotch Blackface (Plate XVI. A), when reared in a true mountain environment, is a small sheep, but when heavily fed for fat stock shows it reaches a weight greater than that of the Southdown or Ryeland. The face and legs are either black or "brockit," *i.e.*, black with white patches, the latter being preferred, though excess of white is objectionable. The head is rather short and, in show specimens, very deep and strong at the nose. The horns of the ram are large, coming out level with the head and forming a wide spiral. The fashionable type of wool is long, nearly reaching the ground, and of a coarse and hairy character though free from kemp. Some stocks have a finer and softer wool that can be used for rough overcoatings and blankets, but most of the wool goes for carpet manufacture and brings a low

price. The average clip under mountain conditions is probably about 4 lb., and the best flocks rarely exceed 5 lb. The general conformation has been immensely improved in recent times, and the modern sheep has a good back and gigot, though the wither, as in all mountain types, is often narrow and sharp. The quality of carcass, whether as lamb or mutton, is first class. The tail is naturally shorter than in other breeds, reaching only to the hocks; as in other mountain breeds it is frequently left uncut.

The Blackface occupies practically all the heather-clad or "black" hills of Scotland, up to altitudes of 3000 feet. The highest grazings formerly carried wether stocks, the male sheep being kept on till they were two, three, or even four years old, but many such stocks have been displaced either by breeding ewes or by deer. Most of the lambs not required for breeding are now sold either fat from the hills in the latter part of summer, or as stores in autumn. On the higher grazings the Blackface is kept pure, while on the lower hills the ewes are crossed with Border Leicester, or in some districts with Wensleydale rams. The cross lambs, "Greyfaces" or "Yorkshire Crosses" respectively, make excellent mutton at from seven to fifteen months old, though some are sold as fat lambs. The Blackface is exceedingly hardy. Generally, the ewe hoggs destined for breeding are sent to the low country to be wintered (on grass only), but the ewes live on the mountain throughout the year and get no artificial feeding except a little hay, and that only when the ground is covered with hard frozen snow. The ewes are prolific. Under hill conditions twins are not generally wanted, but good draft ewes when taken to the low country give up to 140 per cent. of lambs.

The Lonk is found in the mountainous district of West and South-West Yorks, East Lancs, and North-West Derbyshire. It is a larger, longer bodied, and rather longer legged sheep than the Scotch Blackface, with often more white in the face. The tail is long, reaching almost to the ground. The fleece is considerably finer and both denser and heavier than that of the Scotch. The quality of the mutton is

excellent, but the breed is distinctly less hardy than either the Scotch Blackface or the Swaledale. Wensleydale and Leicester rams are those principally used for crossing, where crossing is done.

The Swaledale (Plate XVI. B), another useful and hardy breed, is also somewhat larger and longer bodied than the Scotch Blackface. The fleece is shorter and finer in front, but is coarse on the breech, and kemp is quite as common. The face is black or dark grey, with a "mealy" (grey) nose, and the legs are spotted. Swaledale lambs are said to fatten rather more readily than Scotch Blackfaces, and the ewes to milk rather better, but the hardiness is probably not so good. This breed is found from Swaledale westwards to the Pennines and into Westmorland.

The Rough Fell, also known as the Kendal Rough Sheep, is a closely related breed found in an area centred on Kendal and embracing parts of Yorkshire, Lancashire, and Westmorland. It is larger, somewhat rougher in conformation, and shorter wooled than the Scotch Blackface and shows a brownish tinge in the face. It is regarded as a hardier sheep than either the Swaledale or the Lonk.

The Derbyshire Gritstone, native to the high Peak district of Derbyshire, is the softest and closest wooled of the Blackface type, and is further distinguished by the absence of horns. The face and legs are mottled with black and white.

The Cheviot (Plate XVII. A) is regarded as derived from the ancient Celtic tan-faced breed, and would thus be related to the Welsh Mountain and to the old soft-wooled sheep of the Western Highlands and Hebrides. It has existed on the hills of southern Scotland from very early times, though formerly the breed was much smaller and probably finer wooled than now. There are some records of crossing with Lincolns and Leicesters about the end of the eighteenth century, but the improvement in size and in mutton qualities has been accomplished mainly by selection. The Cheviot is of medium size, reaching, when intensively fed, about the same weight as the Shropshire. The size of hill-bred sheep naturally

depends on the abundance and quality of the herbage. Mature rams of the best class, in show condition, weigh over 200 lb. The head and legs are white, with occasionally a shade of tan, and covered with rather hard, short hair. The head is rather short and very strong through the nose; the ears short and carried very high, giving the animal a very characteristic alert appearance. Short horns still occasionally appear in the male, but are being eliminated, as is the tan colour of face. The wool is of fine quality, with a somewhat harsher handle than typical Down wool, of medium length (3 to 4 in.), and quite dense on the pelt. Kemp is not common, but does occur. Mountain flocks clip from $3\frac{1}{2}$ to 5 lb., and the better sort of shearling rams reach 10 or 12 lb. The general conformation is good. The body is distinctly long and the back sometimes slack; the hind-quarter is generally good, but the fore-quarter, as in most mountain breeds, tends to be proportionately light and the shoulder rather sharp. The mutton quality is excellent, and the breed, and its crosses, especially those from Southdown and Suffolk rams, are often very successful in carcass competitions. The Cheviot is hardy, but distinctly less so than the Blackface. In Scotland and the north of England it is chiefly to be found on the lower and grassy hills, the heather land being given over to the Blackface. Cheviots are also kept as "park" sheep, *i.e.*, on semi-upland enclosed land, and are then wintered with some turnips and other artificial food. The breed is prolific under good conditions and the ewes are excellent milkers.

There are two main centres of the breed, the one in southern Scotland and the north of England and the other in Caithness and Sutherland. North country sheep are larger, somewhat less compact in build, and longer of head and ear. They have finer but rather more open coats and require more food and generally better conditions.

On the better hill farms the older ewes are crossed with Border Leicesters, and on certain farms only half-bred lambs are bred, the Cheviot ewe stock being replenished from outside sources. Draft ewes are mated either with Border Leicesters

[*C. Reid, Wishaw*

A. Shearling Cheviot Ram, "Dignity"

[*G. H. Parsons, Alsager, Cheshire*

B. Welsh Ram

[illegible], *Hensingham*

A. Herdwick Ram, "Kelso"

["*Agricultural Gazette Photograph*"

B. Exmoor Shearling Ewes

or Suffolks. Cheviot ewes and ewe lambs are often taken far south into England for breeding purposes. Abroad, the breed is popular in Canada and the United States.

The Welsh Mountain (Plate XVII. B) is an original Celtic breed that has been kept almost free from extraneous blood. It is the smallest of the breeds here described, reaching about half the weight of the Leicester or Oxford, and not much more than two-thirds that of the Southdown. The Welsh sheep is rather long bodied, light in the fore-quarter, and the face and legs are either white or of a light tan shade, the latter being commoner and preferred. The rams only are horned. The wool of improved sheep is short, fine, and dense, comparable to Shropshire or fine Cheviot in quality, but the fleece of the unimproved type is often coarse at the breech, and contains much kemp. An average clip for ewes is 2½ lb., rams reaching 5 or 6 lb. The mutton is comparable in quality to that of the Southdown, Cheviot, or Blackface, and indeed is regarded by many judges as the finest procurable.

The Welsh is a hardy breed, living on the higher mountains during summer and being brought down to lower levels for wintering and lambing. The sheep are very active and rather wild, and hence are very difficult to confine. The ewes are good breeders and nurses. Draft ewes are commonly mated with Southdown, Kerry Hill, Border Leicester, Western, or Shropshire rams, and produce lambs of exceptionally fine quality. The breed is found throughout the whole of the mountainous district of Wales, the population being densest in the north.

The Herdwick (Plate XVIII. A) is a breed of rather striking peculiarities, found in the bleak, exposed fell district of Cumberland, Westmorland, and North Lancashire. Its origin is quite unknown, although there is a tradition that the foundation stock came from a Scottish or Norwegian vessel that was wrecked on the Cumberland coast two or three centuries ago.

The size is rather less than that of the Blackface mountain type, though varying a good deal with the quality of grazing.

The rams are generally, but not always, horned, while the ewes are hornless. The face and legs of the lamb are of a deep blue black colour, becoming grey and sometimes eventually white with age. The wool, particularly that on the belly, is often mixed with grey; it is long and very coarse in quality, coarser on the average than that of the Scotch Blackface and, especially in older sheep, frequently contains kemp. Ewes clip from 3 to 5 lb. according to conditions, and rams up to 9 or 10 lb. The shoulder top is generally sharp and the breed is late maturing, but the mutton is of fine texture and flavour. The ewes are often not made to bear lambs till they are three years old, a year later than the normal age. The Herdwick is generally regarded as the hardiest of all British breeds; the sheep subsist largely on heather and juniper, and survive long periods of storm. Draft ewes taken to the low country are generally crossed with Leicester, Border Leicester, or Wensleydale rams, and the progeny make excellent butcher's sheep. The Wensleydale is the ordinary cross under hill conditions.

The Exmoor Horn or Porlock (Plate XVIII. B) is an ancient breed native to Exmoor and the Brendon Hills in North Devon and West Somerset. It is of small size, horned in both sexes, with white face and legs and a dark nose. The fleece is something of the Cheviot type, but rather longer and stronger, though quite as dense. Ewe flocks give average clips up to 5 lb. The general conformation is compact and neat, with a peculiarly rounded symmetry. There is rather frequently a deficiency behind the shoulder. The breed is hardy, but the ewes generally get some roots and hay in winter. The mutton is of good quality.

The Dartmoor, like the Oxford Down and Kerry Hill, cannot rightly be classified in any of the three main groups of breeds. It is intermediate between the mountain and the Longwool types, and in many of its characters stands closest to the hardier of the latter, such as the Wensleydale. Like the true Longwools it owes something to Dishley Leicester blood.

It is larger than any of the mountain breeds proper, and

hornless, short stubs being seen exceptionally in rams. The face and ears are white with black spots, the latter generally somewhat concentrated towards the nose. The fleece is long, curly, and lustrous, of almost typical Longwool quality, and the clip is heavy. The sheep is long bodied, strong limbed, and well covered with firm flesh. The ewes are wintered on grass and hay, and lamb in the beginning of March. The breed is rather late maturing but produces yearling or two-year-old wethers of fine quality. Older ewes are crossed either with Down or with South Devon rams.

The Shetland is an interesting breed, so far little improved, but with certain potentially valuable characteristics. It is very small, slow maturing and thin fleshed, though the texture and flavour of the mutton, in well-fed sheep, are good. The colour is black, grey, or brown (moorit) often with white patches, or entirely white. The fleece is light and of very mixed quality but contains a proportion of very fine soft wool which commands a higher price than that of the Southdown. In Shetland the sheep are not shorn, the loose wool being picked off at intervals and the finest sorted out for the local industry of shawl making. The breed, like others in Northern Europe, is naturally short tailed. At one time the breed occupied the whole of the Shetland Islands, but it has given way to some extent before the Blackface.

Sheep Breeding, Rearing, and Feeding.

It seems necessary to begin this section with an explanation of the names that are applied to sheep of the different sexes at various ages. Age in sheep is reckoned from the time of shearing, which in this country is normally done for the first time at the age of fourteen to sixteen months, and at yearly intervals thereafter. The term *lamb* is not very precisely limited, being sometimes confined to the period before weaning, and sometimes extended to cover the first six, eight, or occasionally ten months of the animal's life. However, at some time in autumn, lambs become, in the north, *hoggs* or *hoggets*, and in the south *tegs*. The sex is

also denoted, males being known as tup or ram lambs, tup-hoggs, ram-tegs; castrated males as wether or wedder lambs, wedder-hoggs, etc.; and females as ewe lambs, etc. After shearing we denote the males as shearling rams or tups and shearling wedders respectively. The terms *diamond tup* and *dinmont* are also applied at this age. The female at shearing becomes a *gimmer* (north) or *theave* (south). Thereafter we have two shear rams, wedders, or ewes. Ewes may also be distinguished according to the number of crops of lambs they have borne, as two-crop, three-crop, etc., the first lamb being borne at two years old. In some districts it is customary to denote age by the teeth, as two-tooth, four-tooth, etc., but these terms are less satisfactory on account of the variation in dentition according to breed and environment.

The average period of gestation in sheep is about 147 days, varying a day or two with the breed. The ordinary practice is to complete preparations for lambing about a week before the elapse of five calendar months from the time of mating. Females are normally mated for the first time as gimmers, to lamb at two years old. Hoggs in good condition will frequently take the ram in early winter, and will then lamb at little over a year; but breeding so early is rarely profitable in the end, and is only to be recommended, if at all, with well-grown sheep under exceptionally favourable conditions. Mountain gimmers, if they are small and ill-nourished, are sometimes given an extra year to develop, lambing for the first time at three. Ram lambs, especially those of the quicker growing breeds like Hampshires, Oxfords, etc., are often used for breeding at seven months old or little more. They should, however, be allotted a smaller number of ewes than old sheep, generally not more than thirty or forty. Shearlings and older rams, so long as they remain active, may have from forty to sixty ewes under mountain conditions, and from sixty to ninety when the flock is in enclosed fields.

The time of mating is limited in part by the time of occurrence of heat in the ewe. Thus Dorset Horns will

frequently take the ram in May, Hampshires as early as July, while mountain ewes often do not come in heat till late September or even well on in October. Apart from this the time of mating is fixed by the breeder in accordance with the average climatic and food conditions prevailing in spring. Thus, in the south of England, on arable farms, lambing may begin with the New Year or occasionally earlier, while in Highland grazings it does not commence till late in April. The customary dates for turning out rams in various flocks are usually closely adhered to from year to year, and vary from the first week in August (early Hampshires) to mid-September (Lincolns), 15th October (Half-breds), 10th November (average Mountain Cheviots), and 22nd November (Blackface Mountain). Rams are left in the flock for about six weeks, which is ordinarily long enough to ensure that practically all the ewes will conceive. The period of œstrum in the ewe lasts about twenty-four hours and recurs, if she does not conceive, after about sixteen days. In lowland flocks where the ewes will have close attention at lambing, it is necessary to record the dates of service. To this end the ram is smeared between his fore-legs with colouring matter so that he leaves a mark on each ewe that he serves. At the end of say, each week, the ewes that have taken the ram are given a distinguishing mark, which remains till spring as an indication of the date of lambing. At the end of sixteen days, the colour on the ram is changed, so that ewes not holding to the first service can be immediately known by the fact that they are marked with two colours. Any such should be examined and, if necessary, clipped about the tail and inside of the thighs. The longer wooled breeds are generally so clipped before tupping begins. Occasional ewes that have failed to hold to the first service should be placed with another ram, in case the second service should also have proved ineffective. If many ewes are being twice marked another ram should be procured; in large flocks it is best to run two or three rams together with a combined allotment of ewes, as the accident of one ram proving sterile will then cause com-

paratively little loss. If, however, the rams fight this plan must be abandoned; also the method is not applicable in pure-bred flocks, where matings are made with close regard to individual merits and faults. Under ordinarily good conditions and on low ground the proportion of barren or "eild" ewes should not exceed 1 or at most 2 per cent. In hill flocks it may reach 3 or 4 per cent. in ordinary seasons.

The number of twins, or at least of double conceptions, depends partly on the inherent fecundity of the ewes, and partly on their treatment before and during the mating season. The smallest number of lambs will be obtained when the ewes are lean and weak, or very fat, or are going back in condition. The highest birth rate, on the other hand, is obtained if the ewes at mating time are in moderately lean but rapidly improving condition. This is assured if the sheep have been in low condition after the previous weaning, by bringing them on slowly till within a week or two of tupping, and then by "flushing" on rape, young seeds, or other fresh nutritious food. Failing a supply of such food they may be given up to a pound per head of concentrate daily, avoiding specially heating or fattening materials. Oats are very suitable. The proportion of multiple ovulations (*i.e.* of heats at which two or more eggs are produced) is highest in the earlier part of the breeding season, this explaining the well-known fact that more twins are usually born at the beginning than at the end of the lambing season. Delay in mating after the time when the ewes begin to take the ram will thus reduce the proportion of twin births. Sometimes twins are not wanted, as, for example, in mountain flocks; ram breeders, too, do not want a high proportion, as a good single ram lamb is often worth more than a pair of moderate twins. Even in ordinary commercial flocks there is often a limit to the number of twins desired—*e.g.* on account of a limited amount of good pasture—and in such cases heavy flushing is only resorted to in years when the ewes are obviously backward. Draft ewes, which are usually sold off the hill in autumn, to be bred for the last time under lowland

conditions, and will generally be wanted in lamb earlier than the normal time, must be brought forward in condition more rapidly than the rest. Rams often require special attention during the breeding season. Longwool or other lowland rams put out among mountain ewes must receive a feed of concentrates once a day at least, otherwise they will very rapidly become reduced in condition.

In countries where the winter is very severe, such as the Northern United States and Canada, breeding ewes are housed in cool barns during winter, going out for exercise only. In this country they are always wintered out of doors. Ewes of the hardier mountain breeds are left on their usual pastures, being gathered to the lower and sheltered areas only at the prospect of stormy weather. Generally they are made to live without hand feeding unless or until they are in rather severe straits, which is only in the wildest weather, or when the ground is covered with hard frozen snow. When given hay unnecessarily they tend to stop foraging for themselves, and (since the supply of hay on hill farms is necessarily very limited) they are then in worse plight than if they had been left alone. This is particularly true if feeding is done during the early part of the winter. Instead of relying on hay to a large extent, the hill shepherd endeavours to save the lower areas of the pasture during late summer and autumn, so that he has a reserve of natural herbage for winter food. Weak ewes, however, must be taken in from the hill and kept in enclosures near the homestead, where they can receive whatever special attention or feeding is necessary. On lowland pasture farms the sheep may run on grass without any additional food during the early part of the winter. Later on they are given up to 2 or 3 lb. of hay, and perhaps, from say a month before lambing, a moderate ration of cake and corn.

On arable or semi-arable sheep farms the winter management varies greatly according to breed, the amount of roots, etc., available, and the time of lambing. Half-bred ewes in the north, due to lamb in March and April, may usually run on grass without extra feeding until towards Christmas. As

the pasture gets bare they are given a limited ration of turnips, say half a ton per hundred ewes per day, or 11 lb. apiece. Later they will generally be folded on turnips for half the day, or overnight, returning to the pastures at other times and receiving perhaps a little hay in addition. When roots are abundant ewes are sometimes folded permanently on the crop; but the method is not always satisfactory, the ewes, though they may keep fat, getting into a soft and unhealthy condition. In any case they should be put back on pasture, with a restricted root ration and some hay, a few weeks before lambing is due to begin. A light daily ration of concentrates will be given from a month before lambing in order to bring the ewes into good condition for milking. In some districts chaffed oat sheaves, straw and grain together, are fed in lieu of hay and concentrate. In March, just previous to lambing, the ration might be: turnips, 20 lb.; oats, peas, dried grains, 1 lb., hay, ½ lb.; varying, the hay particularly, according to the amount of rough herbage on the pasture fields. Draft ewes in the lower districts, that are due to lamb perhaps a month earlier, and are to be fattened along with their lambs, are given somewhat more liberal treatment.

In the south winter rape, thousand headed and marrow stem kales, swedes, and later mangolds will be used instead of turnips, and folding is done for a longer period and more regularly. Clover hay, pea haulm, lucerne, or sainfoin may replace the seeds hay of the north. The general scheme, however, is the same, viz., to keep the ewes as cheaply as possible, without letting them become weak, in the early part of the winter, and then to give the foregoing foods in increasing amounts and to add a concentrate ration as the time of lambing approaches. On sheep farms where the arable land is heavy, as for example in many districts of Northumberland, folding in winter is impossible. In such cases the root crop is stored in autumn and the daily allowance is thrown out to the ewes on grassland. Silage crops are, however, being widely introduced in these districts, and prove a very satisfactory substitute for roots.

Lambing, in hill flocks, goes on in the open, and generally on the mountains, though in some cases the ewes are brought down to lower enclosed pastures. It generally begins in the second or third week of April, and continues throughout the greater part of May. Each shepherd, who will have a "hirsel" of perhaps 25 or 30 score of lambing ewes under his charge, is given a temporary assistant (or at least a half share of the time of such an assistant) for the busy and critical period of four or five weeks. This arrangement makes it possible for the sheep to be seen at least two or three times a day, and will generally ensure that assistance is available in cases of difficult or protracted labour. The chief causes of heavy mortality are snow or heavy rain storms; in the first case the lambs may be buried, or simply exhausted by the cold and the heavy going; in the latter they are very liable to be drowned in attempting to follow their dams over swollen torrents. In bad weather the sheep are gathered into the naturally sheltered areas on the lower ground. Even in good lambing seasons weak ewes and those with weak lambs require to be brought down and fed, but the main part of the flock should be made to travel the ground in a regular way. The natural habit of hill sheep is to spend the night on the hill-tops, to move down to the valleys in the morning and up again in the afternoon, grazing as they go. When the lambs are young, however, and especially if the ewes are in low condition, many will tend to lag behind and to remain on the lower ground, which would then soon become foul and unhealthy. Hence the shepherd must see that all that are able do actually go up the heights in the evening, and this often entails heavy work. The earliest herbage on mountain grazings is the "Draw Moss" or cotton sedge (*Eriophorum vaginatum*) which grows on marshy land. On grazings where this is not abundant care must be taken to preserve it by avoiding over-drainage, and the sheep should have full access to the marshy areas in early spring.

Ewes on arable land will have been classified in autumn in five or six groups according to the period (week) in which

they are expected to lamb. Each batch in succession, as it comes due to lamb, is removed to the lambing field, which should be a good dry pasture with the best available natural shelter. Artificial wind breaks, consisting of hurdles or sheep nets stuffed with straw and set up in the form of a cross, should be placed here and there. In or near the lambing field should be a lambing shed with a hut, in which the shepherd and lambing man spend alternate nights. The

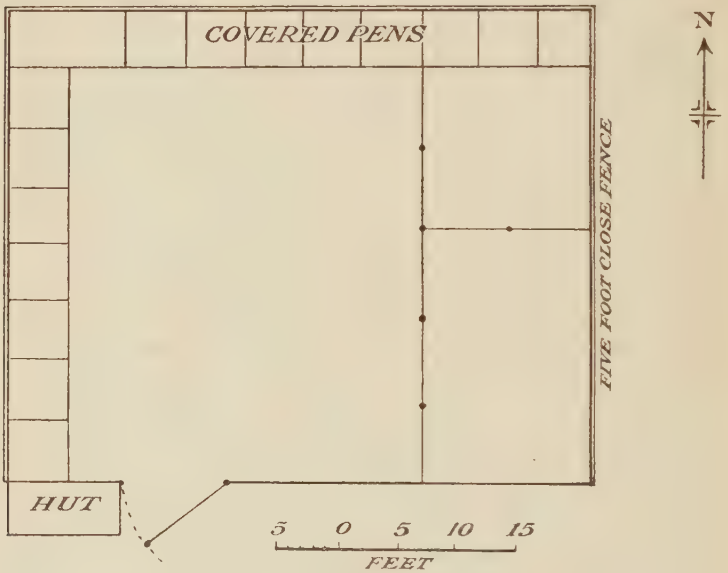


FIG. 60.—Lambing Pen for Flock of 300 Ewes.

shed is usually a permanent structure; some farmers prefer temporary shelters on the ground that they are less liable to harbour disease, but permanent erections, if they receive a thorough annual disinfection, are not open to serious objection. The shed consists of a series of pens, about $4\frac{1}{2}$ or 5 ft. square, with a low roof and arranged to form a hollow square (see Fig. 60). In ordinary cases the central yard is open, but for valuable pure-bred flocks the whole may be roofed in. In any case, the shed should be on dry ground with a sheltered situation and a southern exposure.

During the day the ewes go out in the lambing field; at night they are confined in the central yard of the lambing shed, which should be well littered with dry straw. Ewes lambing at night are placed one in each small pen. Assistance in lambing should not be given too soon, and the assistant should thoroughly disinfect the hands before and after each case. Each ewe and her lamb or lambs may be given a distinguishing dot of colour, in order to avoid any possibility of subsequent confusion. Generally there will be a proportion of triple births, as well as a few orphan lambs. On the other hand there will be many singles and a few ewes whose lambs die. There should be a reassortment, by transferring lambs, so that the flock is made to consist entirely of singles and doubles. In cases where a lamb has died, its skin should be tied over the back of the stranger, when the latter will generally be adopted at once. Other devices, such as that of rubbing the ewe's nose in whisky to deprive her temporarily of her sense of smell, are successful in other cases. In any case reassorted families must be kept penned together until it is seen that they have settled down. Gimmers (theaves) should not be given second lambs if ewes are available.

The ewes and young lambs are kept in the more sheltered fields near the centre of operations for a week or two, and are then put out in lots to the ordinary pastures. On enclosed farms the flock will be split up into lots of similar age, etc., gimmers with double lambs being given the best grass, ewes with singles the worst. Feeding with roots, hay, and concentrate must be continued until grass or forage crop becomes available. This may be as early as mid April in the south, often after mid May in the north. When grass becomes plentiful, roots and hay are withdrawn, and the concentrate is either withheld or is transferred from the ewes to the lambs. Soon after lambing is completed the lambs are docked, ear-marked with the flock mark (or tagged or tattooed with a distinguishing number in pure-bred flocks), and males not for breeding are castrated. In hill flocks the opportunity is taken of enumerating. In mountain sheep the tail is often left long (for protection), but all lambs

that are likely at a later stage to receive roots or concentrates are better docked. Males that cannot be castrated ("chasers" or "rigs") have the tail left long as a distinguishing mark.

Lambing percentages vary greatly with conditions. Mountain flocks in normal years may give from 70 to 120 lambs per hundred ewes, less on the poorer and higher ground, more on the lower and better sort of grazings. In years of storm and flood the increase may be as low as 40 or 50, and occasionally the lambs will barely be numerous enough to replace losses in the older sheep. Probably the average of lowland flocks all over the country is about 130 per cent., and the most prolific flocks reach an average, over series of years, of about 160.

In the north and west, sheep are generally kept on pasture throughout the summer. In the south and south-east, especially on the Chalk and Oölite formations (semi-upland and rather poor arable), the commonest practice is to run the ewes on Down pasture, if this forms part of the holding, during only part of the day; for the rest the flock is folded on forage crops—rye, trifolium, and winter vetches in spring; clover, sainfoin, lucerne, spring vetches, mustard, and rape in summer; rape, mustard, kale, and turnips in autumn. The folding system is of course expensive in labour as compared with ordinary grazing, but it permits the keeping of a considerably larger head of stock than would otherwise be possible, particularly on the drier sort of lands where pasture is not very productive. The stocking of pastures so as to get the best results can only be decided by trial. The best seeds pastures will carry three ewes with double lambs per acre; ordinary pasture perhaps two ewes (with, say, three lambs) per acre; good grassy hill land about one per acre, and the poorer sorts of mountain land as little as one ewe to 5 or even 10 acres. Most mountain grazings have a recognised carrying capacity, which, however, can be improved by treatment, *e.g.* by application of lime and phosphates. In many cases it is of course economically impossible to manure the whole area of the grazing, but highly beneficial results may be obtained from dressing

quite small areas of the better land. The sheep are then able to adjust their mineral balance, and make much improved growth.

Most sheep pastures are improved by the addition of a small number of cattle—say one young store bullock to every five or ten ewes. Such cattle cannot be expected to fatten, as the sheep are continually eating out the finest of the herbage. But they make quite satisfactory growth, and keep the grasses from becoming coarse and from running to seed.

Of the various special incidents of the summer season, shearing is the first. In the south this is done as early as the beginning of May; in north country low ground flocks about the beginning of June; and in the highest mountain grazings as late as the first or second week of July. The date is determined mainly by the time of the natural "rise" of the wool, which becomes apparent a few weeks after the return, with the spring, of a vigorous thriving condition. The time occupied in clipping depends on the type of wool that the sheep carries. With Shortwools, less than a score will represent a day's work for a good shearer, while with Blackfaces, where an inch of wool or more is left on, fully 5 score per day can be shorn. In wool-producing countries like Australia, where sheep-shearing is a specialised occupation, the number clipped, in relation to the quality of the work, is far greater. Sheep may either be washed, in clean stream water, a week before clipping, or may be shorn in the grease. There is a loss of weight of generally from 10 to 20 per cent. if washing is done thoroughly, but the washed wool brings a proportionally higher price. Washed wools can be more accurately valued by buyers, and hence the washing may often be profitable.

The time for summer dipping is generally about three weeks after clipping, when there is just wool enough to carry the dip. Summer dipping has the double object of killing external parasites (keds, ticks, scab-mites, etc.), and of warding off attacks of blow-fly. Sodium arsenite is the standard parasiticide, while tobacco and sulphide of lime

are also used. Sulphur and the sulphides are the most useful preventatives for fly. Many proprietary dips are available and most are entirely satisfactory. A useful dip can be made by boiling 2½ lb. of white arsenic with an equal quantity of washing soda, adding say 8 lb. of flowers of sulphur, and diluting to 100 gallons with cold water. This quantity would suffice for about 100 sheep of average size. The addition of soft soap (say 10 lb.) is useful in helping to keep the sulphur in suspension. Ewes and lambs are generally dipped at the same time.

During July and August shepherds must be continually on the outlook for sheep that have been "struck" by the fly, and the affected parts must be dressed as early as possible with strong dip. Apart from preventive dipping with sulphur dips, the clipping off of locks of dirty wool from about the hind-quarters is important, as the fly is attracted by smell.

Weaning is generally done when the lambs are from three to four months old, *i.e.*, between May and August, according to the date of lambing. At weaning the ewes are put out to the poorest and barest pastures, in order that the flow of milk may be dried off, while the lambs are given the best and cleanest grass available, fields having generally been rested for the purpose, or they are folded on fresh forage crops. Clover aftermaths are ideal for the purpose, only in this case the herbage must be dry when the lambs are turned on, otherwise many of them may get hoven. Most store lambs are disposed of by the breeders at large sales, which commence in June, July, or August according to the district; at the same time, or generally a little later, the breeder buys in ewe lambs to replenish his breeding flock, unless a proportion of the home-bred lambs is being retained for the purpose. Draft and cull ewes are disposed of at other special sales in July, August, or September. On most arable farms, and on the better mountain grazings, ewes are kept in the breeding flock until they are of a certain definite age. This is generally four and a half years (four shear or three crop), but sometimes a year more. On the poorer

mountain grazings, where sheep have a special value when acclimatised and accustomed to the ground, there is no definite age for drafting, but each ewe is retained in the flock so long as she remains active and healthy. Even in flocks where ewes are drafted out at a fixed age, the younger ewes must be looked over and unhealthy animals, bad milkers, and ewes with defective teeth or udders culled out. Draft ewes are brought in to good pasture, or folded on forage crops, as soon as the flow of milk has ceased, and are brought forward rapidly so that they may be in good condition for early tupping. Generally the draft lot is examined and culled, so that the major part may be sold as fully guaranteed, *i.e.*, certified correct in udders and mouths. A second lot will be made of those that are broken-mouthed but otherwise correct, while unhealthy animals or those with defective udders, etc., are sold separately for fattening.

Hill ewes after weaning, and until say October, are herded on to the higher parts of the grazing in order to conserve the lower areas for winter use. Lambs that are not sold at weaning time are allowed to rejoin the flock after about ten days, by which time the ewes' flow of milk will have ceased.

In autumn all sheep must be kept off marshy ground, water meadows, etc., as otherwise they are liable to pick up large numbers of liver-fluke larvæ.

Winter dipping is done during spells of good weather in autumn, generally in October, but either before the commencement or after the close of the tupping season.[1] Dips composed of coal-tar acids—*e.g.* carbolic and cresylic acids—are usually preferred at this season, as apart from their insecticidal action they help to waterproof the wool. Purity of the materials is very important, as crude materials like pitch oil may discolour and otherwise damage the wool.

Besides skin parasites, maggots, and liver-fluke, all

[1] In certain parts of the country there are Government regulations requiring dipping to be done at least twice a year, and between certain specified dates.

mentioned above, there are many diseases and parasites of sheep that must be guarded against. Foot-rot is common in most breeds when they are on wet land. The ordinary preventive is to walk the flock through a foot-bath containing 1½ in. of a disinfectant and astringent solution. A suitable material is a 2 per cent. solution of white arsenic dissolved by boiling with alkali. The solution should not touch the skin, and sheep that fall in the bath must be carefully washed. The foot-bath must be covered and padlocked when not in use.

Garget or udder clap, inflammation of the womb after lambing; scour in lambs; lung, stomach, and intestinal worms; sturdy; louping-ill or trembling; braxy; scrapie; and several other troubles are often responsible for serious loss. In each case the flockmaster must endeavour to avoid such loss by general good management as well as by special preventive measures.

Sheep often get all the water they require from plant sap, rain, and dew, and under such circumstances do not drink; but in spells of dry weather they do so freely, and water should always be offered. Rock salt laid down in pastures often assists in keeping sheep in thriving condition. On many mountain pastures, especially where the soil is deficient in lime, great improvement in growth and general health can be secured by supplying mineral mixtures. Herding can be greatly facilitated by placing the supply of salt or of mineral in the area which the sheep are wished to graze.

Ewe lambs for breeding may be selected from home-bred stock if this be kept pure; indeed, on the poorer mountain grazings, home-bred sheep are much more likely to survive than others introduced. On the other hand, breeders who produce cross-bred lambs for the butcher should obtain ewe lambs from others who specialise in the breeding of such. In either case the animals should be selected carefully and individually, and the number bought or retained may well be 10 or 20 per cent. greater than actual requirements in order to allow for subsequent culling.

Breeding hoggs should be so wintered as to keep them in healthy growing condition, but should not be made fat. Those from mountain grazings must generally be wintered on low ground, and those from extensive mountain districts like the Scottish Highlands have sometimes to travel a hundred miles or more for wintering. Such are, almost invariably, wintered on grass alone, even if this means that they become rather reduced in condition. Root feeding is undesirable because after such artificial treatment the sheep do not take kindly to their native hill-sides. Ewe hoggs on arable or semi-arable farms may run on grass until well on in the autumn, when they are folded on roots for a gradually increasing period of the day. Later on, in January, or earlier or later according to the time of commencement of root feeding, the temporary incisor teeth begin to break off, so that roots must thereafter be fingered and fed in boxes. An allowance of 16 lb. of roots (hardy yellow turnips or swedes) and ¾ lb. of hay will suffice for those of ordinary size (80 to 100 lb. live-weight). If such materials are not available in sufficient quantities, the bulkier concentrates such as dried grains, cotton cake, and oats, may be used, mixed with a little chaffed oat straw or pea haulm. As soon as grass is available the hoggs will go out on the poorer and higher fields, the better being of course reserved for the ewes. They will be shorn a week or ten days before the milking ewes, because the wool "rises" earlier. They join the ewe flock generally some weeks before the mating season, or when the old ewes are drafted out. In some flocks the gimmers (theaves) are not put to the ram until two or three weeks after the ewes, the object being to secure better weather and food conditions at their lambing time. In some mountain flocks the gimmers as well as the hoggs are "wintered away."

Fattening.—Sheep (or lambs) may be got ready for the butcher at various ages. The earliest fat lambs are killed at about three months; there is a considerable supply in the south by early May, and in the north by June. Few sheep, except ewes and rams that have been used for breeding, are

now older than twenty months when they reach the fat market, although occasional lots of two- and three-year-old mountain wethers are still to be seen.

The earliest fat lambs are usually the produce of draft ewes. The latter are purchased by farmers of the better arable land in August (South) or September (North). Either fully guaranteed ewes or broken-mouthed ones (if they are young) may be bought, the latter being generally cheaper but requiring to have their roots cut during winter. Some are sold already tupped, others will generally be put to the ram without delay. They are well fed during winter, lamb early, and from that time onwards are intensively fed, receiving perhaps 1½ lb. of concentrate per day along with roots and hay. Later, they get the best available pasture, running at, say, two or three per acre on first year seeds. As soon as the lambs will eat they are fed with concentrate, either along with their dams or separately. The lamb food is generally a rather complex mixture containing such materials as linseed cake, bran, broken peas, kibbled or flaked maize, oats, etc., with broken locust beans to render it as palatable as possible. If folding is practised the lambs are run before the ewes, *i.e.*, they are allowed access to the standing crop by means of hurdles through which the ewes cannot pass, the latter following on to clean up. As soon as the lambs are fat (the ewes will generally be fat enough) they are marketed together with their dams. Early lambs of this sort, weighing perhaps 70 to 80 lb. live-weight or 35 to 40 lb. carcass, command a high price; but the ewe will often bring less than she cost the previous autumn. Shropshire, Southdown, and Oxford rams are perhaps those most widely used for the production of such lambs, but Leicesters and Border Leicesters give good results with Down ewes.

The produce of draft ewes is succeeded on the market by selected single lambs from regular breeding flocks on the better arable farms, and by July and August lambs of many breeds, not excluding pure-bred Blackfaced Mountain, will be found on the fat markets. In all such cases there will

have been no store period—the processes of rearing and fattening having been combined. Later on there come lambs that have been reared as stores, weaned, very frequently sold by breeder to feeder, and finished off by the latter. The most forward of these, weighing perhaps 80 lb. or more at four months old, will be fattened, in a period of a few weeks, on clover aftermaths or other forage crops, receiving about 1 lb. per day of highly nutritious concentrate; they make rapid gains, as high as 4 or 5 lb. weekly. Hampshires, Oxfords, and crosses of these with Longwool and half-bred ewes, are the favourite types for this system. Rather less forward lambs may have rape or cabbage to follow the other forage crops, and will reach the market by September or October without having been fed on roots.

Lambs for "hogging" are carried on as stores, first on grass or forage crops and later on roots, until they are considered sufficiently grown to be fattened. Their general treatment meanwhile will be the same as that of ewe tegs for breeding. In most markets, under present conditions, a fat weight of not more than 120 or 130 lb. should be aimed at, even if the sheep are capable of reaching far greater size. Heavy sheep give joints that are too large for modern taste, and bring a lower price per pound. Moreover, live-weight increase becomes more expensive as the limit of growth is approached. There is also a desirable pitch of fatness beyond which it is easy to go with the fatter breeds like Oxfords or Leicesters. Lambs and young tegs are rarely too fat—the difficulty is usually to get them fat enough—but large fat carcasses, especially during spring and summer, are generally in poor demand. As a rule, therefore, tegs are kept as stores, and as cheaply as possible, until they weigh from 60 to 90 lb., according to breed, and are then put up for fattening, the latter process occupying from two to four months. The following are examples of winter fattening rations, based on a live-weight of 100 lb. (which is actually a rough average weight for fattening tegs), and each supplying a little under 3 lb. of dry matter, about 1·6 lb. starch equivalent and 0·25 lb. protein equivalent. On such rations

a live-weight increase of about 0·3 lb. per day, or rather more than 2 lb. per week, could be expected.

(1) 16 lb. swedes, ½ lb. clover hay, ¼ lb. dried distillery grains, ¼ lb. Egyptian undecorticated cotton cake, and ¼ lb. flaked maize.
(2) 16 lb. yellow turnips, ¾ lb. seeds hay, ½ lb. barley, ¼ lb. broken peas, ¼ lb. linseed cake.
(3) 10 lb. mangels, ¾ lb. meadow hay, ½ lb. oats, ¼ lb. linseed cake, ¼ lb. decorticated cotton cake.

Apart from questions of ruling prices for feeding stuffs, the following points require attention in rationing:—In the early part of the winter feeding season—October and November—roots are liable to cause scouring and other disorders. The change from grass or summer forage crops to root feeding should therefore be made gradually, and the root ration should at first be limited. Again, if wet weather occurs and the sheep on the root land become obviously uncomfortable, they should be returned to pasture and have the roots conveyed to them. Thirdly, a proportion of the roots should be stored so that there may be no need to feed them in a frozen condition. Many experienced feeders store the whole crop and slice the roots throughout the feeding period.

Feeding sheep are occasionally housed in cool airy sheds. Housing may result in a substantially improved live-weight increase if it happens that outdoor conditions are bad. But in dry weather, even if it be very cold, outdoor sheep do quite as well. The common practice on light soils is to fold the sheep on the root land, moving the fold forward as the crop is consumed so that the ground may be evenly manured. When large numbers are being fattened they are best divided into lots of not more than say 200. A man can tend about 250 fattening tegs where roots have to be cut, or a man with a boy assistant may do 400. A small portable engine for driving the root cutter effects a great saving of labour.

In spring and summer, hoggs or wedders of the later

maturing breeds are fattened on grass or forage crops, with or without the addition of concentrates. Fat sheep may be clipped as much as a month before the normal time for breeding stock.

Hoggs in wool, but with the wool dry and clean, may yield from 50 up to 55 per cent. of their live weight as dressed carcass, the average of market sheep being nearer the former figure than the latter. Newly shorn sheep give about 5 per cent. more. Heavy fat wethers may dress up to 65 per cent. or occasionally more.

Goats.

Goats are valued either for their fleeces or their milk. In the first class are the Cashmere and the Angora, of which the latter is by far the more important commercially.

The Angora is native to the province of that name in Asia Minor. It is of a whole white colour, small in size (60 to 100 lb. live-weight) and horned in both sexes. The fleece (mohair) varies a good deal in quality, but in the best specimens is extremely fine, silky, and lustrous. Typically it is from 8 to 10 in. long and hangs in separate and well-defined ringlets. Four lb. is an average weight of fleece, but superior specimens shear 6 lb. and occasionally up to 14 lb. Fine mohairs have a distinct use in the manufacture of plushes, velvets, and bright lustre materials, and command a price comparable to that of fine wool. The quantity used annually in the Bradford district runs into thousands of tons. The flesh of the young and fat Angora is said to be good. The breed is not very prolific, twins being rare, and the annual increase being generally under 80 per cent. Angoras require a dry climate but are otherwise hardy, and thrive under semi-arid conditions where sheep do not prove a complete success. The chief mohair producing countries, in order of importance, are South Africa, Asia Minor, and the United States (Western and South-Western States).

Milch goats are of several breeds; the best known are the Toggenburg and Saanen (Swiss), the Nubian, and the Maltese. In Britain we have the imported Swiss and Nubian types,

as well as somewhat ill-defined sorts like the Anglo-Swiss, Anglo-Nubian, and Anglo-Nubian-Swiss derived from crosses of the foregoing with the native type. Goats' milk is comparable in composition with cows'—somewhat more variable though probably rather richer on the average. It is often more easily digested by delicate persons, and has the advantage that it can be reckoned to be free from tubercle bacilli, which are the commonest of the more dangerous organisms found in cows' milk. Does of good type reach yields of 3 to 5 quarts per day and milk for six or seven months. The best lactation yields recorded are between 200 and 250 gallons, and the average in good strains is over 100 gallons. Goats, as is well known, will live on almost any sort of herbage, and in mountainous districts, or wherever food is scanty, they form a valuable source of milk. It seems unlikely, however, that they will ever become commercially important in lowland districts where improved dairy cattle can be kept.

CHAPTER VI

PIGS

THE pig belongs to the non-ruminant section of the Artiodactyla or even-toed ungulates. All our domesticated swine are descended from at most two closely related species, namely *Sus scrofa*, the wild pig of Europe and North Africa, and *Sus vittatus*, of Eastern and South Eastern Asia. The eastern type is distinguished from the other chiefly by its shorter and wider head.

The earliest known domesticated pig, which has been named *Sus scrofa palustris*, existed in the earliest Neolithic times, its remains being found along with those of the *Bos brachyceros* (*longifrons*), and the dwarf sheep and dog of the same period. Like them it was very small and slightly built, and had probably been introduced from outside Europe, as no evidence has ever been found of its evolution from the native wild type. It may probably have come from Asia, and hence have been derived from *Sus vittatus* rather than from *Sus scrofa*. In later Neolithic times there occurred a development analogous to that which has been traced in cattle, namely, the original small domesticated type was gradually replaced by another, which in all its characters shows an unmistakable resemblance to the European *Sus scrofa*. It is to be distinguished from the latter only by its slightly smaller size and lighter tusks. Whether this new pig represents a fresh and independent domestication of the native species, or whether it was the result of crossing the wild type with the old *palustris*, will probably never be known. At all events the *palustris* type gradually disappeared, and the European domesticated swine of early historical times must be regarded as practically pure descendants of the native wild boar. Of our modern breeds

the Tamworth is probably the nearest kin to this type, but even that has been dashed with other blood.

In China, Siam, etc., there has existed from very early times a markedly different type of swine, distinguished by its wide head, short, dished face, low legs, and its extraordinary aptitude to fatten. This so-called *Sus indicus* may probably be another old derivative of *Sus vittatus*. It reached the Mediterranean countries in Roman times, and several breeds, such as the Neapolitan, were formed by crossing it with the native stock. During the eighteenth and early nineteenth centuries a good deal of *indicus* blood was introduced into Britain, both directly from China and Siam and through the Neapolitan. This admixture decreased the size and fecundity of the British stocks, but greatly improved their fattening qualities. The influence of the imported stock is most evident in breeds like the Berkshire and Middle White, least so in the Wessex, Tamworth, Large White, etc.

Most of our modern breeds have been evolved, or at least have been moulded into their present form, within the past fifty years. Previous to the formation, in 1884, of the National Pig Breeders' Association, there were no societies of breeders and no published registers of pedigrees. Breeding was carried on in rather a haphazard manner, and although there were recognised local types like the Berkshire, Tamworth, and Yorkshire, their characters were very variable and often very different from those of the breeds that now bear the names.

Pigs are of course valued solely as meat producers, but the meat may be utilised in different ways, and accordingly different types of animals have been evolved. Briefly, the pig products of chief importance are bacon and hams (cured meat), fresh pork, and lard. In Britain lard never constitutes the primary object, and hence we have only two main types, the pork and the bacon.

The size and type of porker demanded by the consumer varies from district to district. In general a pig of 120 to 140 lb. live-weight (yielding a carcass of about 100 lb.) commands the best price per pound. Well bred and skilfully

managed animals reach this weight at 5 or 5½ months old. In some southern markets, notably in London, a smaller animal, weighing perhaps 100 lb. live- or 65 lb. carcass-weight is preferred. In certain northern industrial areas a much larger and fatter type of porker, running up to 250 or 300 lb. live-weight, can still be sold; but the market is a declining one and is always more severely affected, during periods of over-production, than that for small pork.

The conformation desired in a pork pig is comparable with that of a beef steer or a mutton sheep. The highest-priced cuts are obtained from the back and hind-quarter, and hence a wide, thickly fleshed back and heavy ham are wanted. At the age indicated pigs are still in rapid growth and are hence unlikely to be too fat. Therefore early maturity is important, and indications of this — a short, wide head; a low-set, blocky, wide and moderately short body; and thick flesh—should be sought for.

The size of pig desired by bacon curers is larger, varying from 200 to 260 lb. live-weight (equivalent to 150 to 190 lb. dressed carcass). Rather narrow limits as to weight are laid down by many curers, and larger or smaller animals are paid for at lower rates. In general the smaller weights (200 to 210 lb.) are preferred in the south, while for northern markets 240 to 260 lb. is the usual standard. Pigs of good type, given time to develop the necessary amount of lean meat, will reach bacon weight at an age of 6½ to 7½ months.

The true bacon type is relatively longer of body and generally somewhat higher on the leg than the pork type, but of good depth of body, which should be uniform from front to rear. The width throughout is relatively less than in the pork type, but should be very uniform from shoulder to rump. The jowl, neck, and shoulder should be light, as these produce the cuts of least value. The shoulder particularly must be neat, smoothly laid, and should not project beyond the general outline of the side. The side, being a valuable cut, should be long, deep, and smooth, of uniform depth throughout, and thick at the flank. The loin should be thick, the hind-quarters long and of good width, with the ham well

developed, but neat and firm, *i.e.*, not flabby. When the animal has been correctly fed the carcass will contain a high proportion of lean meat, with the back fat about 1½ in., or not exceeding say 2 in. in thickness. The meat will be firm in texture, the fat free from oiliness and of a clear white colour. The skin should be thin and free from wrinkles. A small head and light bone are obviously desirable.

The distinguishing characters of the two types are to a certain extent fixed in the various breeds. Thus, for example, the Large White and Tamworth which are long and rather lean in build, but relatively slow maturing, are essentially bacon breeds. The Berkshire on the other hand, being shorter, wider, smaller framed and earlier maturing, is admirable for pork and good for small bacon, but is unsuitable for producing the larger type of baconer. Other intermediate breeds such as the Large Black, with a certain amount of selection and appropriate management, can be successfully used for either purpose. Crosses are very often preferred for commercial use. The Large White and Middle White make an excellent cross for bacon, while the Middle White and Berkshire cross makes a very profitable porker.

Apart from the special points desired for special purposes, there are certain qualities that are desirable in all breeds and types. Robustness of constitution is one; there must be continuous weeding out of puny and weakly animals. Another is sufficient strength of limb to carry the carcass; to this end the legs should be straight and strong, and the pasterns stout, short, and nearly perpendicular. The temperament should be quiet and docile; nervous and excitable or savage animals are always unsatisfactory as breeders. Prolificness is of obvious importance from the commercial point of view, and it is to a great extent hereditary. Hence breeding stock of both sexes should be chosen from among the progeny of dams that have consistently borne large litters. Large litters are of no value unless their dams are able to rear them. Hence sows that do not rear their litters well should be discarded from the breeding herd; and, since each sucking pig has its own

teat, females of the more prolific breeds should not be retained for breeding unless they have twelve well-developed and regularly placed teats. Sows with ten, or even a smaller number, occur frequently. Finally, colour is of some importance. White pigs are preferred by bacon curers because the carcasses of black or red animals are liable to show pigment in the mammary region — the well-known defect called "seedy-cut." On the other hand, in hot, sunny climates white pigs are liable to suffer from sun scald or blistering, while the dark breeds are relatively immune from the trouble.

British Breeds.

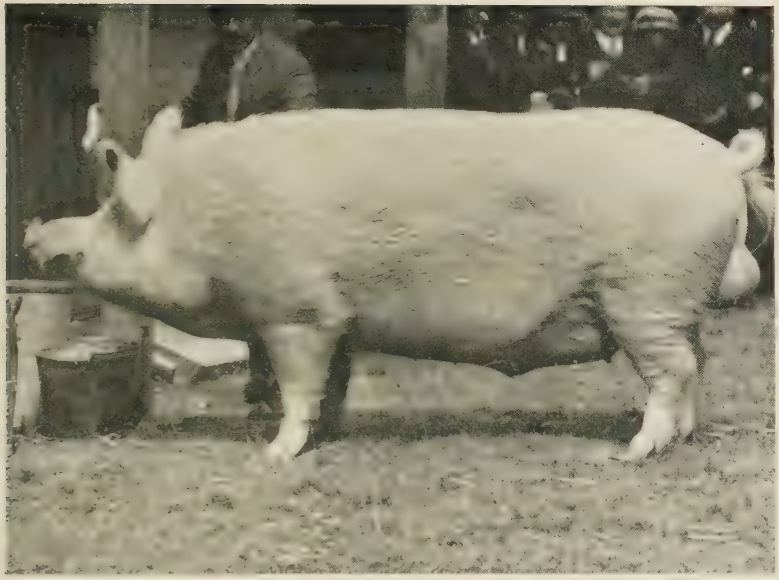
There are now twelve recognised breeds of pigs in Britain; each has its own Breed Society and pedigree record, with the exception that the Large and Middle Whites, the Berkshire, and the Tamworth are all under the care of one (the National Pig Breeders) Association. Some of the modern breeds are derived from local types whose history goes back for a century or more, but it is clear that nearly all were modified during the first half of last century by the introduction of Eastern (Chinese, Siamese, Neapolitan) blood, and it was only during the past forty years that any of them began to be kept strictly pure. Owing to their rapidity of reproduction, and the generally rather mixed nature of the foundation stock, pigs have proved a very plastic material in the hands of the breeder, and new breeds have been formed and old ones remodelled with comparative ease and rapidity.

The Large White or **Large Yorkshire** (Plate XIX. A) is derived from the early north country pig, which was of large size and white or spotted in colour. Probably it contained but little *indicus* blood. The evolution of the modern breed began before 1850 in the large Yorkshire towns—notably Leeds—the pioneer breeders being largely factory hands. In 1851 a weaver of Keighley, named Joseph Tulley, exhibited at the Royal Show at Windsor a pig of the improved type which attracted a good deal of notice.

The Large White is a pig of great size, being excelled in weight only by the Lincoln Curly Coat. Mature boars reach 7 cwt. in breeding condition, and up to 10 cwt. when fat. The breed standard calls for white skin and hair, but bluish spots are still occasionally to be found. The head is rather long, slightly dished, but the nose not turned up; the ears are of medium size and incline forward, but do not hang down over the face; the skin is fine and carries a moderately abundant coat of straight silky hair. The general conformation desired is that described for the bacon type—light in head, jowl, and shoulder, with great length of body, fair depth of side, and large but neat hams. The Large White grows long and matures rather late. It produces an excellent carcass for bacon, and gives large porkers of fine quality at six or eight months old. The sows are prolific and good milkers, though sometimes less docile than could be desired. The young are hardy and rapid growers. The breed is widely distributed throughout Great Britain, but is commoner in the northern counties of England and in Scotland than in the south. It has been very largely exported, and is the favourite breed in most bacon-exporting countries such as Denmark, Ireland, and Canada.

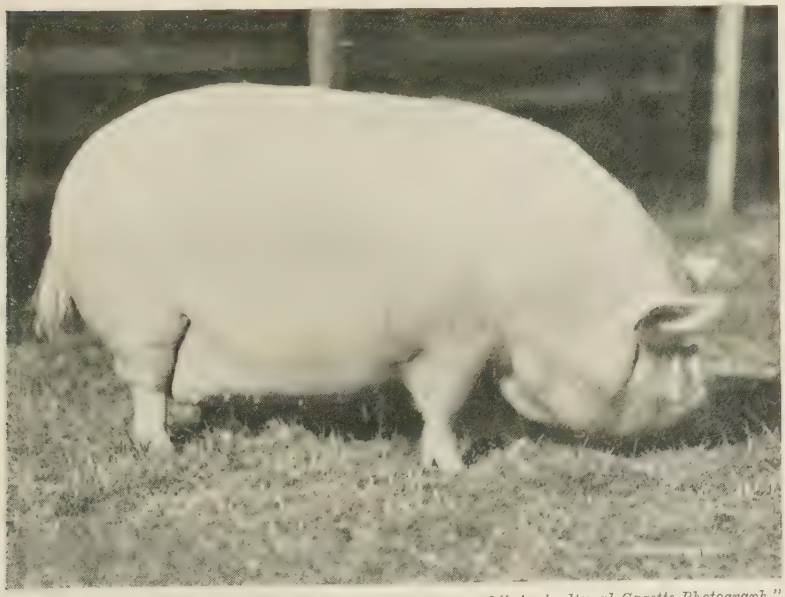
The Middle White (Plate XIX. B) is generally held to have been produced by blending the Large White type with the now extinct Small Yorkshire, which latter was a small, short faced, fine boned, and excessively fat animal, showing a very large amount of Chinese influence. The breed was recognised by the Royal Agricultural Society in 1882, but the type was not definitely fixed until about twenty years later. Sanders Spencer, of Holywell, St Ives, has much of the credit of bringing the breed to its modern perfection.

In weight the Middle White is perhaps 20 per cent. less than the Large White, and is probably the smallest of our breeds, though but little inferior to the Berkshire or Tamworth. The head is short, dished, and the nose turned up; the ears are of moderate size and carried erect; the jowl is rather heavy, and the general build is much shorter, wider and more compact than that of the Large White; the legs



["*Agricultural Gazette Photograph*"

A. Large White Boar, "Spalding Wonder 6th"



["*Agricultural Gazette Photograph*"

B. Middle White Sow, "Wharfedale Royal Lady"

["Agricultural [illegible]"

A. Berkshire Gilt, "Miss Dainty"

["*Agricultural Gazette Photograph*"

B. Large Black Sow, "Easton Bessie I"

are relatively much shorter and the hair generally more abundant. There is in fact but little resemblance between the two breeds. The Middle White matures early and fattens very rapidly on intensive feeding. Its chief use is for the production of young porkers of say 100 lb. live-weight at four and a half months old; when kept till nearly full grown the carcass is liable to become too fat. Much, of course, depends on the methods of feeding adopted, and with careful management good small bacon can be produced. The sows are somewhat less prolific than those of the Large White, and the young pigs do not grow so rapidly in the early stages. Boars of the breed cross remarkably well with sows of the large, prolific, and later maturing breeds, as well as with nondescript country sows of indifferent quality.

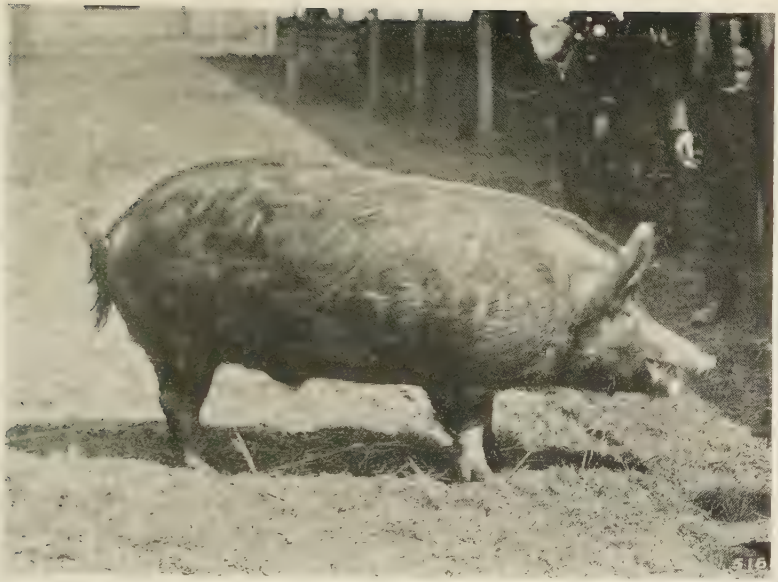
The Berkshire (Plate XX. A) originated in the neighbourhood of the county whose name it bears, and was the earliest improved of British breeds. Culley, in 1789, describes Berkshires as "generally reddish brown, with black spots . . . large ears hanging down over their eyes, short legged, small boned, and exceedingly inclined to make rapidly fat." Other descriptions differ materially from this, and it appears certain that there was a considerable diversity of type. The modern breed is black in colour—rather a rusty black—with white feet, a white tip to the tail, and a white mark on the face. It is one of the smaller of the British breeds, outweighing only the Middle White among those shown at Smithfield. It is smaller in frame than the Tamworth, but equal to it in weight. The head is moderately short and dished, but the snout is not turned up as in the Middle White; the ears are almost erect, but incline forward slightly. The general conformation is somewhat similar to that of the Middle White—a deep and wide body on short legs. The body is, however, proportionately longer, the jowl is slightly lighter, and the tail generally higher set on. The Berkshire is distinctly less prolific than the larger and leaner breeds, aud the young grow slowly in the early stages. Once started they are active, hardy, and excellent grazers.

The outstanding merit of the breed is in the quality

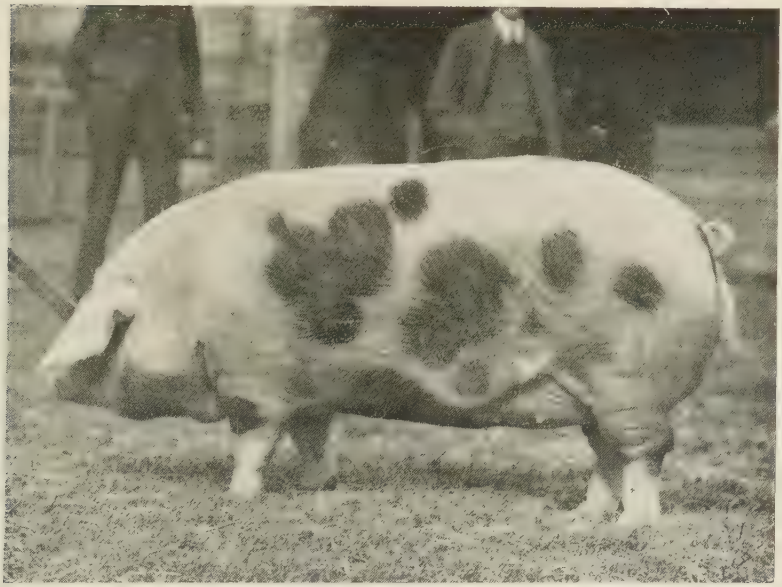
of the meat—in this respect it is comparable to the South-down among sheep and the Angus among cattle. At Smithfield Show pure-bred Berkshires have won fully 90 per cent. of the championships and first prizes in the carcass tests. The breed is at its best in the production of small porkers, but with appropriate treatment makes fine bacon. It is widespread over Britain, but commoner in the south than the north. Abroad it has a very wide popularity, *e.g.* in Canada, United States, Australia, and Argentina. Its dark colour is of course an advantage in the hot and sunny climates. Berkshire boars are excellent either for crossing or grading.

The Large Black (Plate XX. B) is an old breed which has come into prominence only since the founding of its Breed Society in 1899. Before this date the type was confined to Cornwall and Devon on the one hand, and Suffolk and Essex on the other, and there were certain differences in type in the two localities which have since disappeared through the interbreeding of the two stocks. The Large Black is now widely distributed over Britain, and has already been exported in considerable numbers.

Animals of the breed reach weights comparable to those attained by Large Whites. The head is of moderate length —shorter than in the Large White but longer than in the Berkshire. The ears are long and hang down over the face, with their tips, in the approved type, reaching to the nose. The hair is jet black in colour, fine, and generally not very abundant. In conformation the breed is intermediate between say the Berkshire and the Large White, being relatively shorter, deeper of side, and wider backed than the latter. Thus it is neither the extreme bacon type nor is it so wide and compact as the smaller pork breeds. The fore-quarter is usually very light and the hind-quarter heavy. On the average the flesh is not quite so firm and smooth as in the Large White, but the Black is generally regarded as the quicker feeder. The breed is very docile and thrives well out of doors on grass or forage crops. It is reasonably prolific, and the sows are exceedingly good nurses. It crosses well with either the Large or Middle

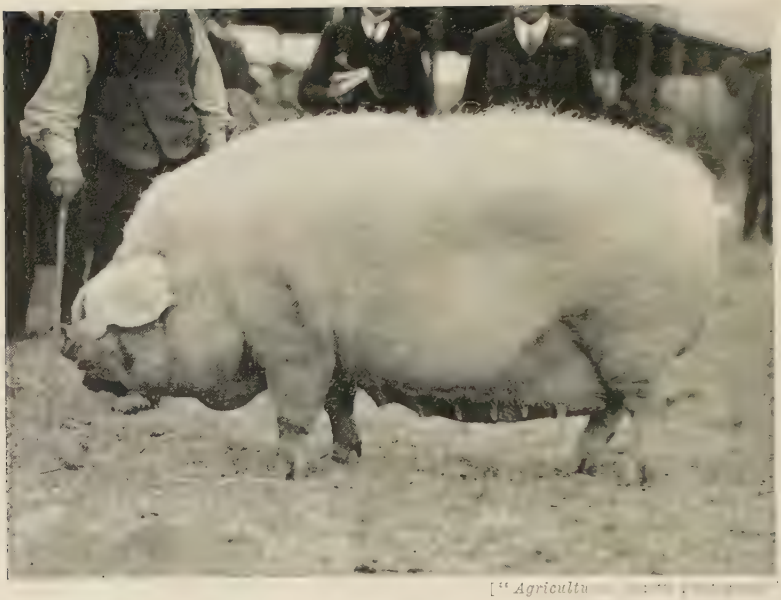


A. Tamworth Boar, "Knowle Warrior" [*C. Reid, Wishaw*



[*"Agricultural Gazette Photograph"*

B. Gloucester Old Spot Sow, "Sonderna Mascot"



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White, and the crosses are preferred by some commercial feeders to either of the pure breeds.

The Tamworth (Plate XXI. A) has its home in the Midlands, particularly in the district about Birmingham. It is of moderate size, reaching a weight about equal to that of the Berkshire, but in build it stands at the opposite extreme from the latter, being very long and relatively narrow of body. The colour is red, varying somewhat in shade, but preferably "golden red hair on a flesh-coloured skin." The head is strikingly long and slim, and the snout straight. The ears are of medium size, rigid, set on rather high, and pointed. The Tamworth was originally very hardy and exceptionally prolific, but some herds, possibly owing to continued close breeding, have deteriorated in these respects. The pigs are active and good foragers; they mature and fatten slowly, but their long smooth sides, neat shoulders, and firm lean flesh render them suitable for the production of the highest quality of bacon.

The Gloucestershire Old Spots (Plate XXI. B) is an old local type which was relatively unknown before the establishing of its Breed Society in 1914. In general conformation it may be described as intermediate between the Large Black and Large White; it is long of body, light of shoulder, uniformly and very smoothly covered with firm flesh which has a high proportion of lean. The head is of medium length and the ears are long and droop over the face. The colour is spotted—clearly defined spots of black on white ground, or *vice versâ*. Gloucester Spots are hardy, prolific, and good grazers, most herds being kept largely out of doors.

The remaining four white breeds are of considerable local importance, but are less widely known than the Large and Middle Whites. **The Lincolnshire Curly Coated** (Plate XXII. A) compared with the Large White, is larger, wider of back, more heavily fleshed, fatter, and rather coarser. The ears are drooping and the coat abundant and curly. The breed is hardy, prolific, and early maturing. **The Cumberland** (Plate XXII. B) again compared with the Large White, is shorter and heavier in build, with a heavier jowl and a

wider shoulder and back. The head is wide, the face short and dished, the ears broad, rather short and hanging over the eyes; the hair is fine and very sparse, sometimes almost wanting. The breed is docile, fattens very readily, and produces a good quality of pork. **The Long White Lop-Eared** (Plate XXXIII. A) is a recent amalgamation of the old Glamorgan and Welsh breeds with the White Lop-Eared pig of Devon and Cornwall. The breed is very similar in conformation to the Large Black, but is pure white in colour. **The Large White Ulster** (Plate XXXIII. B) of Northern Ireland resembles the Large White, but is rather shorter in build, with finer bone, thinner skin, and silkier and much less abundant coat. The ears are long and drooping. The thin skin is favoured by bacon curers.

The Wessex Saddleback (Plate XXIV. A) and the **Essex** (Plate XXIV. B) are local breeds of similar type and colour, being black with a white "saddle" over the shoulders and white forelegs. The Essex breed standard calls for white hind feet and a white tip on the tail, whereas in the Wessex the hind feet should be black and the tail preferably so. The ears are of medium size, with a forward pitch, but rigid. They are rather larger and carried more forward in the Wessex. Both breeds appear to be of hardy constitution and resistant to disease. The sows, too, are good milkers and prolific, and the quality of the meat is good.

Breeding, Feeding, and Management.

Well grown and liberally fed gilts begin to come in heat about the fifth or sixth month, and from this age they must be kept apart from boars. The minimum age for mating, if good results are to be obtained, is eight or nine months in the case of the female; some breeders, particularly those who do not force their breeding stock, prefer to leave them till they are ten or even twelve months old. Too early mating results in a small and unsatisfactory first litter, and may permanently affect the sow's development. Young boars (brawns) may begin to serve at seven or eight months of age.

["*Farmer and Stockbreeder Photograph*"

A. Long White Lop-Eared Sow, "Devonshire Duchesss"

["*Farmer and Stockbreeder Photograph*"

B. Large White Ulster Gilt, "Wood Park Painted Beauty"

A. Wessex Saddleback Sow, "Easington Dark Lady"

B. Essex Sow, "Brooks Perfectus"

The female comes in heat, except when pregnant or nursing, at intervals of three weeks throughout the year, so that it is possible to arrange for litters to fall at any season that may be considered desirable. Œstrum rarely occurs while a sow is in milk, but recurs with great regularity at from three to ten days (and very commonly on the third or fourth day) after weaning; the period of heat lasts about forty-eight hours. The gestation period is sixteen weeks, varying only a day or two one way or the other. Young pigs are left with their dams for a period of from six to twelve weeks. With moderately early weaning, say at eight or nine weeks, the breeding cycle is thus completed in six months, and matters can often be so arranged that a sow farrows regularly, throughout her whole life, at the most desirable seasons, say February and August. Such early weaning, which is the general rule, necessitates frequent and careful feeding of the weanlings, and is only completely successful where there is a supply of skim milk for feeding them. Where such close attention is impracticable it may be better to postpone weaning till the age of ten or twelve weeks, which brings the breeding cycle to between six and seven months. The only material disadvantage of this system is that the farrowing season necessarily changes from year to year. October, November, and December are bad months for farrowing, pigs born then generally doing badly and making slow growth; and hence with a changing farrowing season it may be necessary to let a sow run barren for a month or two, in order to avoid the period in question.[1]

The useful life of a good sow may extend to four or five years on the average; specially valuable pure-bred sows may be kept breeding till eight or ten years old, though they generally become steadily less prolific as time goes on. The average number of pigs reared per litter reaches eight

[1] In countries where the winter is very severe, only one litter per year is usually bred, falling, of course, in spring. Here the young may run with their dams for twelve or up to sixteen weeks. In this case it is common practice to take only one litter from each female, and then to fatten her off.

or nine in the best herds of the more prolific breeds. Seven per litter, or fourteen per annum, may be regarded as a tolerable average for sows of all ages. Gilts will generally average one or two less than mature sows, but much depends on the age at which they are first put to the boar. Exceptionally large litters are not desirable. More than twelve should never be left on a sow, as even if she should have more than twelve functional teats the hindmost pair generally give but little milk, and the piglings that fall to these often make unprofitable animals. Many good breeders limit the number to ten for sows and to seven or eight for gilts, and this may be regarded as a good general rule, to which exceptions should be made only in the case of known deep milkers. Surplus pigs, if healthy and vigorous, may be easily transferred to other newly farrowed sows, if such are available. Most sows take readily to foster piglings, even if these are of a different breed or colour from their own. If no foster parent is available, the surplus pigs (being, of course, the poorest of the litter) must be killed.

Buildings and equipment for pigs vary greatly, from elaborate ranges of sties with cooking or steaming plant—and in some cases hot water pipes for the farrowing pens—to cheap and rude shelters set up in the fields. The sty system has the advantage of economy of labour and of space, but the capital outlay for suitable buildings is heavier, and more skill and care are required in rationing. Pigs running in the open air, consuming whatever green food is available, generally look after their own requirements for vitamins, ash ingredients, etc., and through their freedom and scattered distribution keep relatively free from epidemic diseases such as swine fever. On the other hand, unless they are frequently moved to fresh ground they are more liable to infestation by worms and other parasites. Sty-bred pigs may, and often do, suffer from deficiencies in diet, although they need not do so under skilled management; also, they are perhaps generally less hardy and healthy. It is certain that too close confinement, especially of sows and young growing pigs, may be harmful; on the other hand, pigs in the later stages of

fattening generally make larger and more economical gains when kept indoors. It is probably true to say that under ordinary farm conditions a combination of the outdoor and indoor systems gives the best results—in-pig sows and the older gilts running out on pasture or forage crops during the greater part of the year, while the fattening stock is kept indoors. Young litters and weanlings may be out or in according to the season of the year and the soil and climatic conditions. Light, well-drained land is quite as important for the success of outdoor pig keeping as a mild climate and a sheltered situation.

In the beginning of the present decade considerable areas of grass and partially cleared woodland were laid out as permanent outdoor piggeries, the ground being divided into small paddocks and stocked permanently and exclusively with pigs. This plan has not stood the test of experience; the paddocks become foul, the grass grows rank and coarse so that it is neglected by the animals, and the manure is in effect completely wasted. It is essential, if the pigs are to obtain any considerable proportion of their food directly from the land, that the herbage should be clean and sweet. Hence they should either be folded on arable crops or run on grass as part of a mixed stock. On pasture, animals that are inclined to root freely must have rings put in their noses. Fencing of stout wire mesh is necessary; some shade from hot suns is desirable, and small movable shelters of wood should be provided. The latter are about 8 by 10 ft. for single farrowing sows, and larger in proportion for larger lots. The entrance should face in the least exposed direction, but need not be furnished with a door. The floors should be of wood, and during winter should be kept plentifully littered with dry straw. The general experience is that pigs bred and reared on this system rarely suffer from cold if they are given a dry bed.

Piggeries in which the stock is to be permanently housed may be of any of the ordinary building materials, but must be draught- and damp-proof, well ventilated and well lit, and so constructed as to be easily kept clean and dry. The

air space should not be too great, otherwise the buildings will be cold in winter. A height of 5 or 6 ft. at the eaves, rising to 7 or 8 ft. at the top, will generally be sufficient. Partition walls should be 4 ft. high. Floors of concrete are very suitable from the point of view of cleanliness, but are too cold for the pigs to lie on. Hence where concrete is used, movable wooden platforms should be provided, on which the litter is placed, or portions of the floor may be made of brick or asphalt. Sows and young pigs require more exercise than they can obtain in sties of an economical size, and hence buildings should be so arranged that a proportion of the sties open on to outdoor courtyards or small paddocks. For lots of young pigs it is a good plan to have two sties communicating, in one of which the feeding is done, while the other is reserved for a sleeping compartment, and can be more easily kept dry. Troughs should be semicircular in section, of glazed material, and should be so placed that they can be filled from the feeding passage. Separate direct drainage must be provided for each sty. Farrowing pens should be larger than those for the outdoor system, say 10 by 10 ft., and should be provided with a rail of iron tubing fixed about 10 in. from the floor and the same distance from the wall. This reduces the number of casualties that result from the sow lying on her young.

In respect of feeding, it must be borne in mind that the digestive organs of the pig are of a totally different type from those of the herbivorous farm animals. The capacity of the alimentary canal is, in proportion to the size of the animal, about half what is found in the ox, sheep, or horse. There is no provision such as is made in the paunch of the ruminant, or the cæcum of the horse, for the storage of large quantities of coarse bulky food. In spite of this the pig on full diet eats more food, stated in terms of dry matter and in proportion to its live-weight, than do the other farm animals. The process of digestion is rapid and is dependent only to a very slight extent on the action of bacteria. Thus while the pig can extract practically nothing from the crude fibre of its ration, the more readily digestible nutrients such

as starch and sugar are not subjected to the wasteful process of bacterial fermentation, and are therefore much more efficiently utilised than by the herbivora. The pig's capacity for rapid growth and fattening is remarkably high, owing to its high intake of energy coupled with a maintenance requirement that is not substantially greater than that of other animals. For example, a steer of 10 cwt. live-weight, consuming 24 lb. of dry matter and perhaps 13 lb. of starch equivalent, may make a daily live-weight increase of something over 2 lb., whereas a pig of 200 lb. live-weight, on a ration of 6 lb. of dry matter with a starch equivalent of $4\frac{1}{2}$ lb., may be expected to make about $1\frac{1}{2}$ lb. of live-weight increase. Not only so, but of the steer's live-weight only 60 per cent. is dressed carcass, whereas the pig dresses about 75 per cent. of its live-weight Such comparisons must not indeed be too closely insisted upon, because the steer utilises materials such as straw which are useless to the pig. Nevertheless the pig is an exceedingly efficient machine for the transforming of concentrates and readily digestible food into meat. In general, if this valuable quality is to be exploited to the full, pigs must have a ration of high energy value in small bulk. It is only in the case of pregnant sows, where the storage of energy is necessarily small, that the concentrates can be economically cut down, and coarser and more bulky material substituted.

The fact that pigs are capable of dealing with large quantities of concentrates has led to certain common mistakes in their rationing. Under natural (wild) conditions, pigs feed on a great variety of materials—roots, seeds, leaves, grass, etc., as well as flesh and carrion. Under domestication the foods most largely available are cereal grains and their offals. Such materials appear to be sometimes deficient in vitamins, are often unsatisfactory in respect both of the quantity and the quality of their proteins, and almost generally show an unsatisfactory ash balance, notably a deficiency of calcium. They require to be supplemented with foods rich in protein and ash (such as green leguminous plants, fish, meal, etc.), or with protein rich-cakes and meals plus minerals.

Turning to some of the more important details in pig management, the sow should usually be put to the boar at the first period of heat occurring after her litter has been weaned. Exceptions may be made in the case of animals in very reduced condition, or where immediate service would make the following litter fall in the undesirable season. Sows only rarely fail to "hold" to the boar if mated at the first heat, but are somewhat more likely to "miss" if service is delayed. Recurrence of œstrum is very unlikely to escape notice, so that sows may be taken from the male as soon as they have been served. On the other hand, there is little objection to the practice frequently adopted of running the sows and boar together. A sow may indeed be served twice or occasionally three times, during one period of heat, but this would only constitute a serious objection if the boar were young, or if he were being used to mate with an exceptionally large number of sows, say more than two or three a week.

Pregnant sows should have abundant exercise in the open air up till within a week or two of farrowing. Many small and unsatisfactory litters, and many casualties among the young, result from the sows becoming fat and lazy. In summer all sows should, if possible, be turned out to pasture, a rough but rain-proof shelter being provided. Sows that are accustomed to outdoor conditions will, of course, receive similar treatment in winter, while sty-bred animals should have a roomy court, partly covered and partly open. The maintenance ration for sows of ordinary weights may be reckoned at the rate rather under 1 lb. of ordinary mixed meals (with a starch equivalent of about 70) per 100 lb. live-weight. An addition of about 50 per cent. to this will serve to keep the animal in slowly improving condition, and will at the same time provide for the upbuilding of the tissues of the embryos. A sow of ordinary size (say 350 lb. live-weight) will thus require the equivalent of about 5 lb. of meal daily. This, however, should never all be in concentrated form. Where good mixed pasture, containing clover, is available or where vetches or other green food can

be fed *ad libitum*, satisfactory results will generally be obtained from 2 lb. of concentrate given in one feed each day. In winter, potatoes, kohlrabi, swedes, kale, etc., should be substituted, in quantities proportional to their energy values, for about half the total requirements of meal. Where potatoes, swedes, etc., are used as the vegetable portion of the diet, attention will require to be paid to the protein supply, and a proportion of the concentrate must be somewhat highly nitrogenous.

Each sow, some ten or twelve days before she is due to farrow, should be removed to her farrowing pen, in order that she may have time to become fully accustomed to her surroundings. She must also be more liberally fed, in order that she may be brought into fit condition for nursing. A ration equivalent to about 7 lb. of meal, most of it in concentrated form, fairly laxative in nature and rather rich in albuminoid, will suffice for sows of average size. Sharps, with the addition of 5 per cent. of fish meal and 5 per cent. of linseed cake, form a favourite and satisfactory food. A small allowance of green food should be given. Milk usually appears in the teats about twelve hours before farrowing begins, and four or five hours before the sow will generally gather straw in her mouth and make a nest. The pen should have been thoroughly cleaned, and well-bedded with clean straw, cut into 6-in. lengths. Long litter prevents the piglings from getting about. No person except the sow's regular attendant should be present during farrowing, and generally speaking there should be no interference unless this is absolutely necessary. The chief danger at farrowing is from nervous or excitable sows eating their young, the risk being greatest with the first litter. Such accidents generally begin by the sow taking up a pigling in her mouth, apparently without intent to harm it. In her excited condition she may crush it to death, and if she should chance to break the skin and taste blood, she will generally continue to devour the whole litter. Correct feeding, more particularly an ample supply of protein, greatly reduces such risks. In any case sows that have once eaten a litter should

never be trusted with another. Many pigmen remove the young pigs, as born, to a box or basket filled with straw, and keep them apart from the sow until she has finished farrowing. The piglings' mouths should be examined, and if the four little front teeth are sharp and prominent they should be nipped off with a pair of pliers, the operation being of course performed out of hearing of the sow.

During the first two days after farrowing, the sow will take but little food, and should be offered nothing but a thin slop of sharps, or, if she be in weak condition, warm milk. Even after she recovers, her demands are not at first very large, and will generally be met by a ration of 8 or 9 lb. of meal, in the form of slop, divided into two feeds. Many breeders withdraw green food for the first week or two after farrowing, because they hold that milk produced on such feeding is liable to cause digestive disturbances in the young. The quantity of the ration, as always with pigs, should be regulated according to the appetite, no more being offered at a meal than the animal will clean up in say twenty or thirty minutes. After the first two or three weeks the requirements of the litter, especially if it be a large one, increase rapidly, and the ration may be increased to 9 or 10 lb. (or 12 lb. in the case of large sows with large litters) of meal, in three feeds, with a small allowance of green stuff. The concentrate should also be made more highly nutritious and more highly nitrogenous, by the introduction on the one hand *e.g.* of barley meal and maize meal, and on the other of pea or bean meal, fish meal, etc. A starch equivalent of 70 to 75 and a protein equivalent of 15 should be aimed at.

At three or four weeks of age the piglings will begin to look for food other than their dam's milk, and, especially if weaning is to be early, they must be encouraged with palatable and easily digestible foods. They should be given a shallow low trough placed in a railed-off portion of the sty, in which skim milk or a thin slop of sharps is offered. In two or three weeks more they should be eating freely, and should have a ration of ample amount, rich in protein and

ash ingredients. Males not required for breeding should be castrated between the fourth and seventh week. If the operation is delayed it causes a noticeable check to the animal's growth. "Rigs" (animals in which the testicles do not both descend, and which cannot be castrated easily) must be fed off before they are five months old, as later their flesh takes on the strong flavour of the boar's and is of low value. The age for weaning, as has already been indicated, may be anything between six or seven and twelve weeks. As a rule seven weeks should be the minimum age; eight or nine weeks gives quite satisfactory results if the young animals are skilfully rationed, and fed at least three times daily. Those weaned at twelve weeks will thrive well on ordinary feeding—two meals of concentrate per day, with some green stuff between.

Regarding the rate of growth of the young animals, piglings weighing generally from 2 to 3 lb. each at birth may be expected to reach 30 lb. at eight weeks and 50 to 55 lb. at twelve weeks old. Thereafter, if kept on full rations, ordinary pigs will make fully $\frac{3}{4}$ lb. per day, increasing to about $1\frac{1}{2}$ lb. at an age of six or seven months; for a further month or two the gain is maintained at this rate, after which it declines (see live-weight table, Appendix). Specially selected animals of the larger breeds may give average daily increases of nearly $1\frac{1}{2}$ lb. for their whole lives, *i.e.*, until slaughtered at six or eight months. For short periods of intensive feeding much larger daily increases may be obtained. The absolute rate of increase is of course of minor importance compared with the economy of gain. The highest increases in proportion to the food consumed are given by the young animal, as is the case with other species, and the food cost per unit of live-weight increase rises steadily with age. Thus, a four months' old pig, weighing perhaps 80 lb., produces a pound of live-weight increase from 3 or $3\frac{1}{2}$ lb. of average concentrate, whereas at nine months the animal, weighing perhaps 250 lb., consumes about 5 lb. of meal for each pound of gain. It must of course be borne in mind that the newly weaned

pigling is produced at a high food cost per lb., and that the labour cost of the live-weight increase is highest in the early stages. Nevertheless, it seems certain that meat can be produced at the lowest cost when the animal is slaughtered at from six to eight months of age at a live-weight of 200 to 250 lb.

The intensity of the feeding process must depend on the purpose for which the pig is destined. Those intended to make the ordinary sort of porker (say 100 to 140 lb. live-weight) are kept on a full ration—as much as they will eat—of food that is as concentrated as it may safely be. At the opposite extreme young breeding stock should be given just enough suitable food to enable them to make full growth, but not more; that is, they should not be made fat. Here it will often be economical to give a somewhat bulkier and less nutritious ration rather than to reduce the quantity, but the food should never be high in fibre content. Pigs for bacon will be treated in the early stages on a plan somewhat intermediate between the two foregoing; if fed intensively for the whole period of their lives their carcasses will generally show an insufficient development of lean tissue; but the aim should be to get the greatest rate of gain consistent with obtaining the desirable type of meat.

Regarding the quantity of food to be given at different ages, the feeder will be guided by his experience and by the appetites of the animals, the main principle being to feed no more than the animals will consume in a short space of time at each meal. Nevertheless it is of importance to be able to reckon what will be consumed. Since pigs' rations always contain a high proportion of concentrate, and since barley meal is the old standard feeding stuff, it has become customary to reckon quantities in terms of this material. For practical purposes such foods as peas, wheat-meal, fine middlings, linseed cake, etc., may be considered as equivalent, weight for weight, to barley. Maize is of higher value, the equivalent of a pound of barley being about 0·85 lb. Oats and ordinary sharps are lower, with a barley equivalent of about 1·2 lb.; 4 or 5 lb. of potatoes,

8 to 10 lb. of swedes, kohlrabi or cabbage, 6 to 8 lb. of ordinary green stuff, 8 lb. of separated milk or 12 lb. of whey may similarly replace a pound of barley. On this basis, a pig of 50 lb. live-weight will consume about $2\frac{1}{2}$ lb. barley equivalent (5 per cent. of its live-weight); one of 100 lb., about $4\frac{1}{4}$ lb.; 150 lb., $5\frac{5}{8}$ lb. ($3\frac{3}{4}$ per cent.); 200 lb., $6\frac{3}{4}$ lb. ($3\frac{3}{8}$ per cent.); 250 lb., $7\frac{1}{2}$ lb. (3 per cent.). A pound of meal per month of age is a useful approximation. These figures apply to fattening stock; breeding and bacon animals will have perhaps 15 per cent. and 10 per cent. less respectively. With fattening stock not more than about 10 per cent. of the ration should consist of the bulkier green foods. Others may get perhaps a fifth of their food in this form.

It must be borne in mind that fattening pigs, excepting only sows that are being fattened up after they have done breeding, are in more or less rapid growth, and the ration must provide for maintenance, growth, and fattening. In respect of meeting growth requirements many of the standard feeding stuffs, such as maize, potatoes, barley meal, and the finer wheat offals, are unsatisfactory on account of their deficiency in minerals and protein. The addition of about 10 per cent. of white fish meal or of meat-and-bone meal is commonly resorted to in order to balance the ordinary type of meal mixture. The same result is achieved in other cases by feeding skim milk, but in this case the addition of a little powdered chalk may be beneficial. Good results can also be obtained by the combined use of highly nitrogenous cakes (such as decorticated earth-nut or linseed) and a mineral mixture. The combination of minerals which will give a perfect balance will of course depend on the nature of the particular ration, but the addition of about $1\frac{1}{2}$ per cent. of the following to a typical meal mixture will usually give satisfactory results:—

20 lb. ground chalk.
15 lb. common salt.
5 lb. sterilized steamed bone flour.
2 lb. iron oxide (Fe_2O_3).
1 oz. potassium iodide.

The following are a few examples of rations for pigs made up in each case so as to meet the animals' requirements for energy, protein, mineral matter, and vitamins. The requirements are calculated from the feeding table given on pp. 405 and 407.

1. Weanling at 8 weeks old, live-weight 30 lb.

With separated milk.

70	per cent.	sharps.
29	,,	barley meal.
1	,,	ground chalk.

Feed 1¼ lb. per day with 1 quart separated milk.

2. Weanling at 12 weeks, live-weight 50 lb.

Without milk products.

40	per cent.	barley meal.
40	,,	sharps.
10	,,	linseed cake.
10	,,	white fish meal.

Feed 2½ lb. per day.

3. Bacon pig at 5 months, live-weight 130 lb.

30	per cent.	maize meal.
30	,,	barley meal.
28½	,,	sharps.
10	,,	decorticated earth-nut cake.
1½	,,	mineral mixture.

Feed 5½ lb. per day.

4. Porker at 4 months, live-weight 90 lb.

40	per cent.	barley meal.
20	,,	maize meal.
20	,,	sharps.
18½	,,	palm kernel cake.
1½	,,	mineral mixture.

Feed 4½ lb. per day.

5. Porker at 4 months, live-weight 80 lb.—potato farm.

50	per cent.	pea meal.
20	,,	decorticated earth-nut cake.
20	,,	palm kernel cake.
10	,,	meat and bone meal.

Feed 2 lb. per day, with 7 lb. steamed potatoes.

6. In-pig sows, with grazing or green food.

40	per cent.	maize meal.
20	,,	palm kernel cake.
30	,,	sharps.
10	,,	fish meal.

Feed 3 lb. daily with 10 lb. green vetches, kale, etc.

With regard to the preparation of the food, all hard grains must either be ground or soaked, otherwise they will partially escape digestion. Experiments in the feeding of meals have shown no striking advantage in wet as compared with dry feeding; the great majority of practical men in this country do in fact soak the food, and feed it in the form of slop. This doubtless avoids a certain amount of waste, as meals, particularly light fine material like sharps, are liable to be blown about by the animals' breath and wasted. Except for young sucking pigs and newly farrowed sows, the slop should not be made very dilute, as otherwise the pig's system is overburdened with water and it becomes less resistant to cold. Generally speaking, three or four parts of water to one part of dry food, by weight, is sufficient; pigs receiving their food in this condition will require little drinking water except in very hot weather, but should have water offered. The practice of warming the food to blood heat is an advantage in cold weather, but it is of doubtful profitableness. Cooking should not be done except in the case of materials of questionable soundness such as household refuse, or in that of potatoes, which cannot be fed raw in any quantity with safety. The cooking of ordinary meals, etc., if they are of sound quality, is always definitely disadvantageous. Lastly, it is worthy of mention that distinctly beneficial results have been obtained by providing a free supply of salt and of charcoal.

Where the food is given dry, and water is supplied separately, self-feeders are very commonly used. Holding several days' supply, they have the advantage of reducing labour, and ensure that each pig in a lot receives its full share of the food. Where a full ration is intended to be fed,

as, *e.g.*, with nursing sows or fattening pigs, the best types are generally satisfactory, although there is a tendency with some pigs to gorge themselves and take insufficient exercise, with the result that they suffer from constipation and become unthrifty. For store stock, pregnant sows, etc., they are less useful because these on an unlimited ration quickly become overfat. The method of limiting the energy value of the ration by diluting the meal with husks and other fibrous and indigestible material is not to be recommended.

During the last three or four weeks of the fattening period the effect of the food on the quality of the meat must be considered. Excessively watery rations, such as those containing large quantities of wet brewers' grains, dreg, or whey, should be avoided, as likely to give a watery carcass. On the other hand, maize, linseed meal, and many other materials give a fat of soft oily consistency, while linseed products impart a distinct flavour of its characteristic oil. Fish meal may also cause taints and should be avoided during the last three weeks, though it has been shown that white fish meal up to one-fourth of 1 per cent. of the live-weight may be given without any effect that can be detected. The best finishing materials are barley meal and cooked potatoes, with a limited amount of skim milk. Barley meal alone is completely satisfactory.

The proportion of dead- to live-weight (the head being of course included in the carcass, and the animal not skinned) may be put at 70 per cent. for 100 lb. live-weight, 75 per cent. at 200 lb. live-weight, 80 per cent. at 300 lb., and up to 87 or 88 per cent. for large and very fat animals.

CHAPTER VII

HORSES

THE horse family (Equidæ) forms part of the group of Perissodactyla, or odd-toed ungulates. Zoologists include all members of the family, whether horses, asses, or zebras, under the genus Equus.

The Zebras, which are found only in Africa, include the now extinct Quagga (Cape Colony), the True or Mountain Zebra (South-Western Africa), Burchell's Zebra (Transvaal, etc.), Grevy's Zebra (Somaliland), and two or three more species or subspecies related to one or other of the foregoing. None of the zebras has attained any importance as a domesticated animal, although specimens of several species have been successfully broken both to harness and the saddle. Grevy's Zebra has generally been regarded as the most promising from the utility point of view.

The Wild Asses embrace two African types, the Somaliland and the Nubian; and two Asiatic, the Onager of Syria, Persia, Arabia, and India, and the Kiang of Turkestan, Mongolia, and Thibet. Domesticated donkeys are generally regarded as of purely African origin, but some authors have supposed that Onager blood has been blended with African in some of the larger breeds.

The only truly wild horse now existing is the *Equus Przevalskii* of the Gobi Desert and North-Western Mongolia. Whether or not this wild species has been concerned in the origin of our domesticated horses is somewhat uncertain; that it is not the sole ancestor is fairly generally agreed, most authorities supposing that at least three distinct species are represented among our modern breeds. Although these original species have been crossed and intermingled to a considerable extent, we may still distinguish fairly pure

representatives in the Celtic pony (*Equus celticus*) of the Western Isles; the Arab, Barb, etc. (Oriental light legged type), and the Shire and Belgian (Western heavy legged type).

Hybrids between horses and zebras, asses and zebras, or horses and asses may be produced with comparative ease. The hybrids, however, with rare and doubtful exceptions, are sterile. Of the hybrids the only one of much economic importance is that between the male donkey or jackass and the mare, viz., the mule. The opposite cross, between a stallion and a she ass, is of much less value.

As a preliminary to a description of the various types of horses, some explanation of "points" and gaits is necessary. **The points** are shown and named in Fig. 61. Of the things that go to the making of a good horse, some are related to the special purpose for which the particular animal is to be used, *e.g.* draft, harness, or saddle. Other things are regarded as desirable in all breeds and types, and these may be now briefly mentioned. The head should be of good width between the eyes, and the eyes themselves prominent and of good size. These points denote intelligence and docility. The nostrils should be large and open to permit of free breathing. The neck should be of good length. The shoulder should be at least moderately sloped back, as an upright scapula almost invariably makes for a stilted gait. The back and loin should be short, nearly straight, and heavily muscled, in order to give strength; too short a back, however, is often associated with a lack of freedom in movement, especially at the trot. The hind-quarters should be long and wide, and not too steeply sloping to the tail. Large fore-arms and thighs are important as indicating strength. Chest and middle should be deep in order to give, on the one hand, space for heart and lungs, and on the other, capacity for food. For similar reasons the ribs should be well "sprung" or rounded. The knee should be large, the hock broad, and the cannon bones "flat," *i.e.*, the tendons should be large and set well back from the bone itself, in order to give the necessary strength and freedom of move-

ment. A fair length and moderate slope of pastern are necessary in order to break the concussion when the leg meets the ground, but too much length or slope involves weakness. The feet should be wide in proportion to their

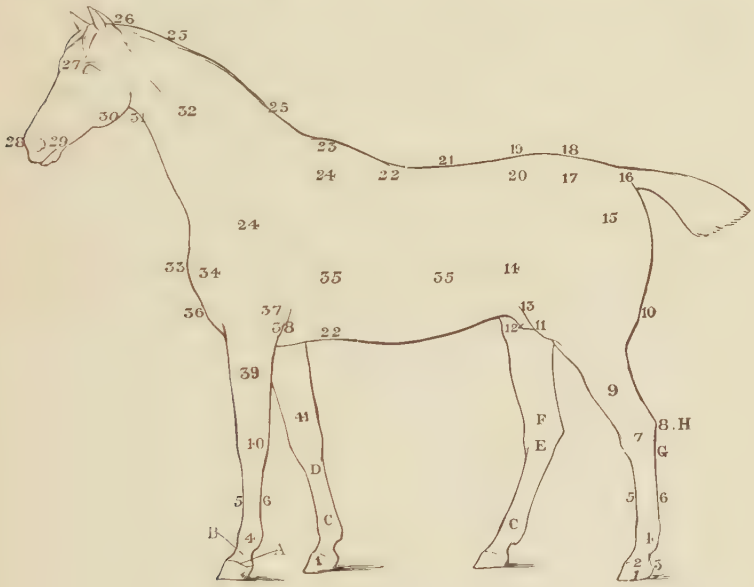


FIG. 61.—POINTS OF A HORSE.[1]

1. Hoof.
2. Coronet.
3. Heel.
4. Fetlock or Pastern Joint. B. The Pastern.
5. Cannon-bone.
6. Back Sinew or Tendon.
7. Hock.
8. Point of Hock.
9. Second Thigh or Gaskin.
10. Haunch or Lower Buttock.
10 to 20. Thigh.
11. Stifle.
12. Sheath.
13, 14. Flank.
15. Hip Joint.
16. Root of Tail or Dock.
17. Rump.
18. Croup or "Quarter."
19. Loins.
20. Point of Hip Bone.
21. Back.
22, 22. Girth or Chest-Measurement.
23. Withers.
24, 24. Shoulder Blade (*Scapula*).
25, 25. Crest.
26. Poll.
27. Forehead.
28. Muzzle.
29. Nostril.
30. Jaw.
31. Throat or Windpipe.
32. Neck.
33. Point of Shoulder.
34. Shoulder.
35, 35. Front Ribs and Short Ribs behind forming the Barrel.
36. Chest or Breast.
37 to 34. True Arm (*Humerus*).
38 Elbow.
39. Arm (or Forearm).
40. Knee.
41. Chestnut, Castor or Callosity.

SEATS OF COMMON DISEASES.

A. Side Bone.
B. Ring Bone.
C. Wind-gall.
D. Splint.
E. Spavin.
F. Thorough-pin.
G. Curb.
H. Capped Hock.

[1] See *The Exterior of the Horse*, by Armand Goubaux and Gustave Barrier, translated from the French by Simon J. J. Hardger, V.M.D. (Lippincott Co., London and Philadelphia.)

length, the soles concave, and the substance of the hoof tough and durable. The legs should be well knit under the body, and should be moved freely and straight.

The gaits natural to most horses are the *walk*, *trot*, and *gallop*. Some horses develop, also naturally, either the *amble* (or running walk) or the *pace*. The chief additional gaits to which horses may be trained are the *canter*, which is a restrained and modified gallop, and the *rack* or "single-foot." Of these various modes of locomotion the simplest are the trot and pace. The trot is a diagonal two-beat gait, that is the off fore and near hind move together and meet the ground at the same time, making one beat; the near fore and off hind similarly move together and produce the second beat, the intervals between the beats being the same. When the trot is performed at a moderate speed, the one pair of feet meets the ground just as the other pair leaves it, and the mark of the hind foot will be found covering that of the fore. Young horses frequently "strike" or "click" when at the trot, the toe of the hind shoe meeting the sole of the fore shoe just as the former is meeting and the latter leaving the ground. When urged beyond an ordinary speed most animals pass into a "flying trot" in which, before each beat, there is a period of suspension when all four legs are off the ground. Here the mark of the hind foot will generally be found to be a few inches in front of that of the fore. In the trot the rider generally "posts," that is he rises in his stirrups with one or other pair of legs—generally with the near hind and off fore—and thus escapes the jolt of the second beat.

In the pace (which is rarely found except in American pacer-bred animals) the left pair and the right pair of legs move together, as in a camel's "trot." This sidelong gait is both uncomfortable and unsafe for a rider, but in a harness animal it is not objectionable, and is on the average slightly faster than the trot. The American pacing record for a mile is about 1 minute 55 seconds, as against 1·58 for the trot. The trot and pace are the only two-beat gaits shown by the horse. The third possible one (shown by the galloping dog) in which the two forelegs move together,

making one beat, while the two hind make the other (the conventional gait illustrated in all old racing prints), is never shown by horses.

The walk, amble, and rack may be grouped as symmetrical four-beat gaits—that is, each foot is moved in different time from the others and makes a distinct beat, while the movement of the left leg, in each case, is similar in amount and opposite in time to that of its right fellow. The succession in general is: left hind, left fore, right hind, right fore—left hind, etc. The chief difference between the three is in speed. The amble is performed at a rate intermediate between those of the walk and trot. It is a good saddle gait, comfortable for the rider and easy for the horse, and is favoured in many countries where long distances have to be travelled. The rack is performed at a speed faster than that of a sharp trot. It is a showy gait, and a comfortable one for the rider, who has nothing to do but to sit still in the saddle. It makes, however, very heavy work for the horse; animals are trained to it with difficulty, and it is regularly developed only in the American Saddle breed.

The canter and gallop are unsymmetrical gaits, *i.e.*, the movements of the one leg are not matched by those of its fellow. A horse may canter or gallop either "right leg leading" or "left leg leading," and may be trained to strike off in either way or to "change the leg" at the rider's will. In the gallop, the four beats follow each other in very rapid succession, and there succeeds a relatively long interval in which each leg in turn leaves the ground, and the horse is suspended in mid air with all four gathered under him. The succession (in the case of an animal galloping with right leg leading) would be: left hind, right hind, left fore, right fore—left hind, etc. The canter, apart from being more restrained, shows a different succession, viz. (right leg leading), left hind, left fore, right hind, right fore—left hind, and the spring, following the four beats, is proportionately shorter. The canter is a very comfortable gait for the rider, and in saddle-bred animals it forms an easy one for the horse.

The particular gaits that are required vary with the

purpose for which the animal is to be used. Heavy draft animals perform all their work at a walk, but should be able to trot freely and easily on occasion. The principal gait of the harness animal is the trot (or alternatively and exceptionally, the pace), but a free and rapid walk is also to be desired. Ordinary saddle horses should be trained to walk, trot, canter, or gallop at the rider's will, while the American ("gaited") saddle horse is required to show five distinct gaits, viz., the walk, trot, canter, and rack, together with the walking trot, or one or other of two somewhat similar slow movements.

From the utility point of view horses (including ponies) are classified as saddle, harness, draft, and pack. The first type is required to carry a rider; the second to draw a light vehicle at considerable speed; the third to pull, and the last to carry loads at a moderate or slow speed.

The Saddle Horse.—As far as concerns this country, the hunter and the polo pony may be taken as representative types of saddle horses. The former is typical of the larger, the latter of the smaller sort of animal for actual utility purposes.

Hunters are classified according to the weight they are judged to be capable of carrying in the field. One system is to make 12 stone the minimum for the light weight class, and 13 stone 7 lb. the minimum for the heavy. More elaborate classifications are adopted at the larger shows. The qualities specially desired in a hunter may be summarised as follows:—

1. *Speed.*—He must be fast at the gallop, and should show a collected and easy movement at the walk, trot, and canter. Very high action is generally incompatible with great speed, and hence is not wanted.

2. *Staying Power.*—He should be able to gallop at a good speed over three or four miles of ordinary mixed country, taking fences as he goes. Staying power can never be finally judged without actual test, but a large nostril, a good width between the angles of the jaw, and a deep capacious chest are useful indications of it.

3. *Strength.*—The muscles chiefly used in galloping under

a rider are those of the back, loin, and hind-quarter. The back and loin should be short, wide, and heavily muscled, while the quarter should be long, wide, and strong, the muscles carried well down towards the hocks, and the gaskin or second thigh wide from front to back.

4. *Durability.*—The limbs and joints must be strong enough to withstand the stresses to which they are subjected. The heaviest of these occur during jumping—on rising they are greatest in the hock, and on landing in the tendons and ligaments of the forelegs and the bones of the pasterns. Hence broad clean hocks, neither too straight nor too bent, and large bone and tendons in the foreleg are points of great importance.

5. *Temperament.*—The animal must have plenty of courage and yet be susceptible of such training as will place it completely under the control of its rider. This may be judged to some extent by the appearance of the head, the expression of the eye, and the carriage of the head and ears. A long neck, fine at its junction with the head, generally makes for easy control by the bit, whereas a short, thick neck generally means difficulty in control. Jumping ability, which is largely a matter of temperament, cannot be judged except by trial.

6. *The Comfort of the Rider.*—The withers should be high and fairly thin, to provide a comfortable seat. The gaits should be smooth and easy and the stride long, the legs being carried rather low, especially at the canter and gallop. Good length and slope of pastern also make for comfort by breaking the impact of the leg on the ground.

In size, hunters range from about 15·1 to nearly 17 hands,[1] most being between 15·3 and 16·2. The weight-carrying capacity is not a function of height but rather of general build, the shorter legged and stronger boned animals being generally up to greater weights, if somewhat slower, than the taller and finer boned types.

The polo pony may best be described as a weight-

[1] The height of horses is measured to the withers, and the unit used is the hand = 4 inches.

carrying hunter in miniature, with, if possible, a greater measure of intelligence, in order to permit of greater refinements in training. Great nimbleness and particularly cleverness in turning are necessary in playing ponies. The regulation height for polo ponies in this country is 15 hands for both stallions and mares.

The American or Gaited Saddle Horse is an interesting type that has been developed in the direction of great style and symmetry, combined with high endurance at moderate speed, and a great measure of comfort for the rider. It is, however, inferior to the hunter in strength, speed, and fencing ability.

Harness Horses.—Among harness horses we may recognise three somewhat distinct types. The carriage horse or hackney type is distinguished by great symmetry of build; compared with the hunter he has a stronger and less refined head, which is carried much higher. The neck is thicker and more crested, the withers lower and thicker, and the general conformation, especially in the hind-quarter, more rounded. The action is totally different. A good harness horse must trot with speed, resolution, and style; the fore foot, when lifted, should almost touch the elbow, and the hock should be well flexed. The stride must be long, and the action should be "up and forward" rather than "up and down." The foot need not and should not strike the ground violently; the leg should be fully extended before it comes to earth and should come down gently. In judging harness horses in the showyard the chief importance is given to symmetry and action. From the utility point of view endurance and wearing qualities are equally important.

The coach type is adapted for heavier and faster road work. Compared with the foregoing, the coach horse is of larger size, say from 16 to 16·2 hands, with greater length of limb, and shows greater speed, stamina, and wearing qualities, with less extravagant but still smart and stylish action. In past times the breeding of coach horses was a very large industry, but the commercial importance of both coach and carriage animals is now comparatively small.

In some other countries, notably in the United States, a third type of harness horse has been evolved, which is commonly known as the light harness type. This is a horse of light and rangy build, showing more resemblance to the thoroughbred than to the hackney, and with great speed and endurance when before a light buggy. The characteristic gait is the trot, though sometimes the pace is shown. The American Standard Bred is used as a basis for producing this type.

Of chief importance to agriculture is the **draft type**, more especially the heavy draft; the qualities desirable in the latter may be summarised as follows:—

1. *Strength.*—This is to some extent proportional to weight, but depends also in large measure on the development of particular muscles, and on the efficiency of the transmission of the available power through the limbs. The back and loin should be short, wide, and thickly covered with muscle, while the quarters should be long, wide, and well muscled down to the thighs. Arms and gaskins should be broad, with the muscles prominent. As far as concerns the transmission of power, the legs should be closely knit to the body and placed well underneath it; they should be moved freely and straight. Serious defects under this head would be a long and bare back, narrow quarters and thin upper thighs, wide waddling action in front, or a tendency for the hocks to twist outwards when they are submitted to the strain of draft.

2. *Endurance.*—Lung space—a deep capacious chest—is of importance, but perhaps of rather less consequence in the draft animal than in horses that work at a high speed. Most horses that fail to stand up to severe and long continued work in draft, do so from an insufficient capacity for food. The good feeder, who can be known by his well-rounded ribs and deep capacious belly, will generally be found to have great endurance, whereas the tall, light-ribbed animal with flat sides readily gets weak and out of condition.

3. *Wearing Qualities.*—The useful life of the draft animal is terminated, in a large majority of cases, by some break-

down in the feet and legs. Constitutional unsoundnesses like roaring and stringhalt excepted, the common troubles are sprain of the tendons, ring-bone, side-bone, and navicular or other disease of the foot. Hence special attention must be paid to "underpinning." The cannon bones should be of good size, but must show "quality," *i.e.*, they should be clean and hard, with the tendons well set back and large, giving the leg a markedly flat shape. The pasterns should be of good length (they can, however, be too long) and should slope at about 45°. The foot should be wide at the hoof head, neither flat nor steep, and the substance of the hoof should be tough and strong.

4. *Speed.*—The draft animal should have a long stride and a free, straight, active, and easy walk. An animal with a short-stepping, stilted action either cannot walk out at a reasonable speed, or does so with a great wastage of effort. The animal should be able to trot freely and rapidly when required, but there is no particular advantage in high knee or hock action.

5. *Temperament.*—The draft horse should have pluck and energy, without being highly strung or intractable. His head will show less refinement, but more strength than that of the saddle type; it should be carried fairly high and the expression should be alert.

As regards size, it may be said that a height of 17 hands is sufficient for a heavy draft animal, if he be thick of body and proportionately built. Many good horses are under this height, and females are generally considered big enough for breeding if they reach 16·2. A good weight for a mature gelding in working condition is 14 to 15 cwt., or say 1600 lb. The largest stallions in show condition occasionally exceed a ton (2240 lb.), though 18 cwt. or 2000 lb. is more usual.

The light draft type may be described as something intermediate between a heavy draft and either a weight-carrying hunter or a harness horse. It will show less weight and strength than the heavy draft, but more activity and speed. Since it will have to perform a good deal of its work at the trot, it should show freedom and ease in this

gait, and should be hard limbed and sound of feet to withstand the heavy tear and wear of fast street work. In general the light draft type is not a very profitable one to breed as the market requirements for vanners and light lorry animals tend to be filled with misfits from other classes, *e.g.*, indifferent harness or saddle horses, or undersized specimens of the heavy draft breeds. It makes, however, a useful farm horse for the lighter classes of soils, or for districts where cultivation is of the less intensive sort.

The pack type of horse is one of minor and decreasing importance, since its use is confined to districts where the roads are not fit to carry vehicular traffic. The most generally useful sort of animal for the purpose is a large pony or small sturdily built horse, sure-footed, active, and docile.

British Breeds.

The Thoroughbred or English Racehorse (Plate XXV. A) is of almost pure Eastern blood. It may be said to have originated in an importation of some forty mares—mostly Barbs—made by order of Charles II. During Charles' lifetime these mares were kept as a Royal Stud, and at his death they were sold and dispersed throughout the country. Of many stallions imported both before and after that time, by much the most important were the Byerly Turk, imported in 1689, Darley Arabian (1706), and Godolphin Barb (1724). The blending of these different blood lines, together with long continued and rigorous selection on the basis of racecourse performance, has produced an animal that is far superior in speed to any modern Oriental breed, and is by much the fastest horse in the world.

Modern thoroughbreds show a good deal of variation in type, chiefly because there is, and has been, little or no selection except that based on racecourse performance. The height varies from the one extreme of under 14·2 to the other of over 17 hands, the average being probably between 15·2 and 15·3. The head is lean and refined, the eye large and prominent, and the nostril wide. The courage

of the breed is proverbial, but the temperament is sometimes objectionably highly strung and occasionally vicious. The neck is long, rather thin, and muscular, with a large windpipe, and is carried rather low. The chest is capacious, but deep rather than wide, and the shoulder is preferably but by no means invariably well sloped. The back and loin are very generally short, straight, and muscular; the croup is commonly of good length but varies in conformation, being sometimes level, with the tail set on rather high, sometimes rather steeply drooping. The bones are clean and hard, with the tendons sharply defined and well set back. Small "weedy" bone and long slight pasterns are objectionable. The movement should be smooth and easy, the stride long, and the legs carried rather low. The commonest colours are bay and brown, with chestnut, grey, and black following in order of frequency.

From the utility point of view, Thoroughbreds vary greatly in value. Natural toughness, stamina, courage, and speed are constant assets, but it is only when these qualities are combined with strength and wearing qualities that they make for commercial value. The long legged, slightly built, and light boned animal is often a good flat racer, but is of very little actual use. Such "weedy" animals, if they fail to win on the racecourse, are almost worthless. On the other hand, the stoutly built and big boned animal, even if he is not fit to win races, forms an ideal saddle horse sire and possesses great commercial value. Many breeds of light legged horses are indebted to the Thoroughbred for endurance, speed, and courage.

The Arab (Plate XXV. B) has a history that stretches back for several centuries, yet the probability seems to be that it should be regarded as an offshoot of the still older Barb race, having been taken to Arabia from Northern Africa about or just before the beginning of the Christian era. Careful selection, with very special attention to such qualities as courage and endurance, has been carried on by the Arabs for a long period, and the modern breed is distinguished by these qualities in a very marked degree. From the Thorough-

bred, to which he is closely related, and which he resembles in a general way, the Arab is distinguished by several fairly constant characters. On the average he is smaller, 14·2 hands being perhaps the average height. The head is wider between the eyes and tapers more towards the nose; the neck is more arched, the head is carried higher and the shoulder is more oblique; the croup is generally longer and typically more level, with the tail higher set on; the withers are commonly rather thicker.

In speed the Arab is far inferior to the Thoroughbred. He is, however, capable of carrying a heavy weight in proportion to his size and is unexcelled in endurance; many animals have been ridden fifty or sixty miles a day for several days on end. In long distance tests the breed is generally supreme. An Arab Horse Society has been established in England, and published the first volume of its stud-book in 1919.

The Hunter and the Polo Pony (Plate XXVI.) cannot yet be regarded as breeds in the strict sense, but are rather commercial types. Registration, with a view to the establishment of actual breeds has, however, commenced, foundation stock being entered by inspection. Hunters generally carry a large proportion of Thoroughbred blood, the other elements in their breeding being very varied. "Clean bred" hunters are by no means unknown, but it is exceptional to find Thoroughbreds with the necessary bone and substance. The polo pony breed, when formed, will contain the blood of several native breeds of ponies such as the Welsh, Exmoor, and Dartmoor, blended with that of the Thoroughbred and Arab.

The Hackney (Plate XXVII. A) originated in Lincoln and Cambridge in the late seventeenth and early eighteenth centuries, and soon afterwards spread into Norfolk on the one hand and Yorkshire on the other. These latter counties became identified with the two chief types, which were later blended together. The Hackney carries a considerable amount of Eastern blood, and is indebted to the same Darley Arabian that became perhaps the chief foundation sire of the Thoroughbred.

The early type was a fast weight-carrying trotter, and many records exist of animals that could travel sixteen miles and more in an hour, carrying 15 or even 18 stone. In recent times the Hackney has been bred as a high class carriage-horse, and chief importance has been attached to symmetry of form and high and stylish action. Much of the ancient stamina, however, remains, and the breed has been kept very free from unsoundness, so that, when allowed to move naturally (*i.e.*, without the weighted shoes and tight bearing reins of the showyard), Hackneys make good useful road horses.

The average height is perhaps 15·2 but there is a considerable amount of variation in this respect. In all its characteristics the Hackney conforms to the type of the British harness horse, previously described. Indeed, very few animals except pure bred Hackneys are ever successful in the harness classes at the more important shows.

The Hackney Pony, apart from its smaller size and pony character, resembles the Hackney, but is a distinct breed. The size, for the showyard, must not exceed 14 hands.

The Cleveland Bay (Plate XXVII. B) might be fairly accurately described either as a heavy and powerful coach-horse, or as a fast and active light drafter. A native of Yorkshire, it has a history that goes back more than two hundred years, though its improvement, especially during the middle part of last century, was effected partly by an infusion of Thoroughbred blood. The Cleveland will generally measure 16·1 to 16·3 hands, is stoutly built, with hard clean legs and fast but not very high action. The colour is bay with black points. He makes a good farm horse for the lighter sort of soils, and a useful light lorry animal for street work. The mares cross well with Thoroughbreds, producing weight-carrying hunters or artillery animals and, with Hackney sires, a large type of carriage-horse.

The Yorkshire Coach is rather closely related to the last, but carries a considerably larger proportion of Thoroughbred blood. Standing 16 or 16½ hands, bay or brown in colour, the Yorkshire is more slightly built than the Cleveland,

with refined head, long quarters, and fast, stylish but not extravagantly high action. It is a typical coach breed.

Ponies.—Of the native British ponies the smallest, and certainly one of the oldest breeds is the **Shetland**. Standing generally under 40 in. in height (the maximum height for mature animals is 42 in.), the Shetlander is very stoutly built—rather like a heavy draft animal in miniature—and very strong for his size. In their native isles the ponies are used as pack animals, especially for the carrying of peat. Being generally docile and easily trained they are very popular as riding ponies for young children. They are also used as pit ponies in cases where the galleries are too low to permit of the use of larger animals.

The Western Isles Pony, or light type Highland pony, is native to the Hebrides, some of the best and most typical being found on Barra. It is generally between 12 and 13 hands high and is of good saddle conformation, though often steep of shoulder and rather sickle-hocked. The quality of bone is excellent, and the breed is very active and of course exceedingly hardy. It is used, like the Shetland, principally as a pack animal.

The heavy or Mainland type of **Highland Pony**, frequently spoken of as the Garron (Plate XXVIII. A), is found in the Central Highlands of Scotland, notably in Perthshire. Averaging nearly $14\frac{1}{2}$ hands in height, the breed is very stoutly built, distinctly "drafty" in type, with rather heavy shoulders and thick withers. The neck is highly crested, the mane abundant. The "bone" is sometimes too round and the legs carry, in winter, a good deal of long feather. Distinguished for his great hardiness and longevity, the Highland pony is used by the smaller glen farmer as an all purpose horse—for riding, driving, hauling, and carrying; during the stalking and shooting seasons many find employment in carrying deer or game.

Of rather similar type to the last is the **Fell Pony** of Cumberland, Westmorland, and West Yorks. It is generally some 2 or 3 in. smaller than the Highland, but is built on the same general plan—thick and short of leg, with

large bone. It is believed to be descended from the old Galloway pony, which was famed for its toughness and strength. The **Dales Pony** of East Yorks and Durham is larger than the last, and might almost be regarded as a small draft horse, since many specimens exceed 14·2 or even 15 hands in height. The general conformation is rather massive, but the breed is both sure footed and fast. In past times many were employed for pack work, and some are still taken for colliery purposes; their chief use, however, is for farm work on the smaller holdings of the Dales.

The Exmoor and Dartmoor are ponies of saddle type. The latter stands about 12·2 hands, the former perhaps 2 or 3 in. less. They have well-bred heads, good shoulders, and hard bones, but, rather frequently, drooping quarters and sickle hocks. Crossed with small Thoroughbred or Arab sires, they produce excellent riding ponies.

The New Forest shows rather less breeding than the foregoing, and generally a heavier and more upright shoulder; the legs, however, are better built. Forest bred specimens run from 12·2 to 12·3 hands. The breed is a harness rather than a saddle one.

The Welsh Pony (Plate XXVIII. B), which has existed from very early times on the moors and mountains of Wales, is a breed of very considerable importance, forming perhaps the most valuable foundation stock for the production of both harness and polo ponies. Two types are recognised and are registered separately in the stud-book. The smaller and lighter type (under 12 hands) is of saddle conformation, while the larger (up to 12½ hands) has higher action and is more of the harness type. In general these ponies are very hardy and enduring, and show great freedom and speed in movement.

The Welsh Cob is derived partly from the foregoing, with an infusion, in early times, of some Thoroughbred, Arab, and Hackney blood. Typical specimens measure from 13·2 to 14·2, have durable limbs, and show fine action and great staying power.

The Heavy Draft Breeds now recognised in Britain are

[*Clarence Hailey, Newmarket*

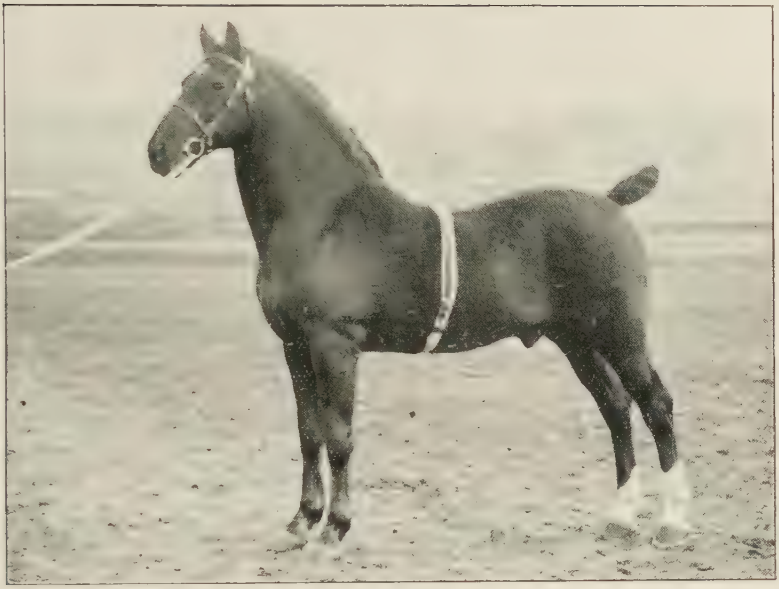
A. The roughbred stallion, "Bend Or"

B. Arab Horse, "Skowronek"

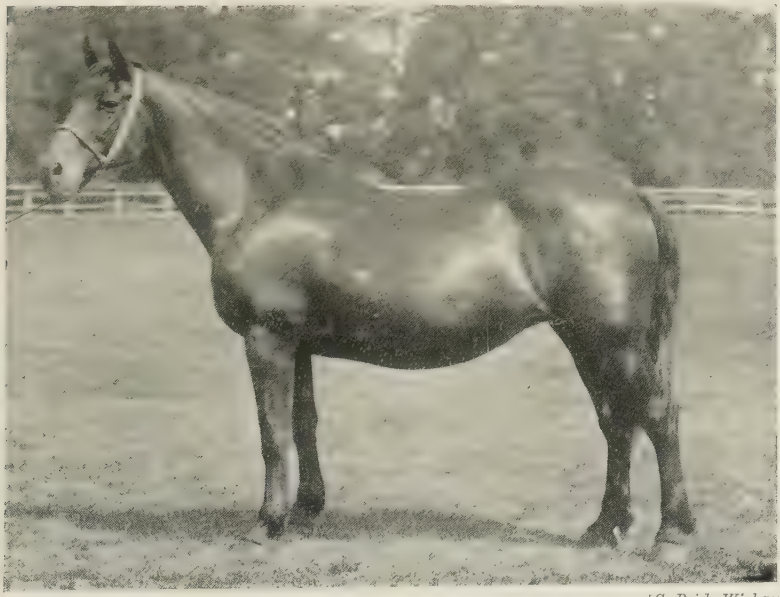
A. Heavy-weight Hunter, "Orator"

[*G. H. Parsons, Alsager, Cheshire*

B. Polo Pony Mare, "The Pheasant," and Foal by "Rupert"



A. Hackney Stallion, "His Majesty"



[*C. Reid, Wishaw*

B. Cleveland Bay Mare, "Madam"

A. Highland Pony Mare

B. Welsh Pony, "Searchlight"

["Agricultural Gazette Photograph"

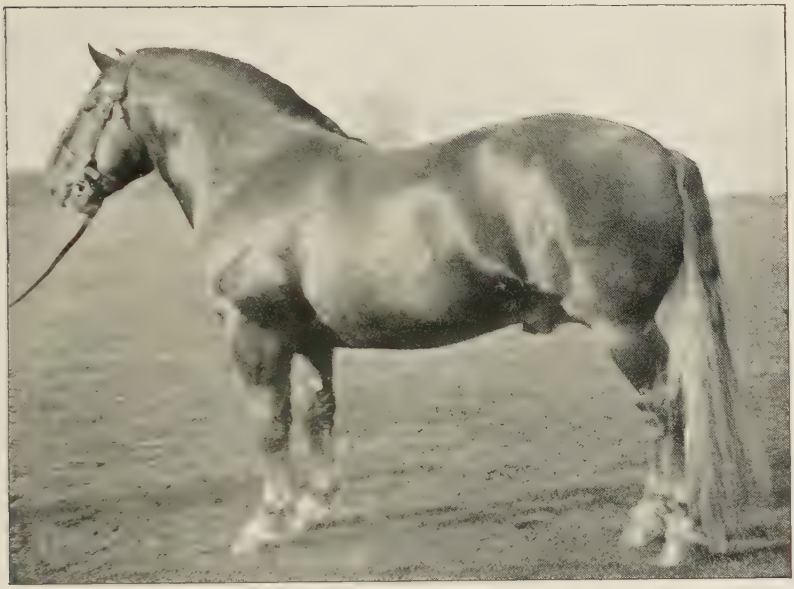
A. Shire Stallion, "Sundridge Nulli Secundus"

["Agricultural Gazette Photograph"

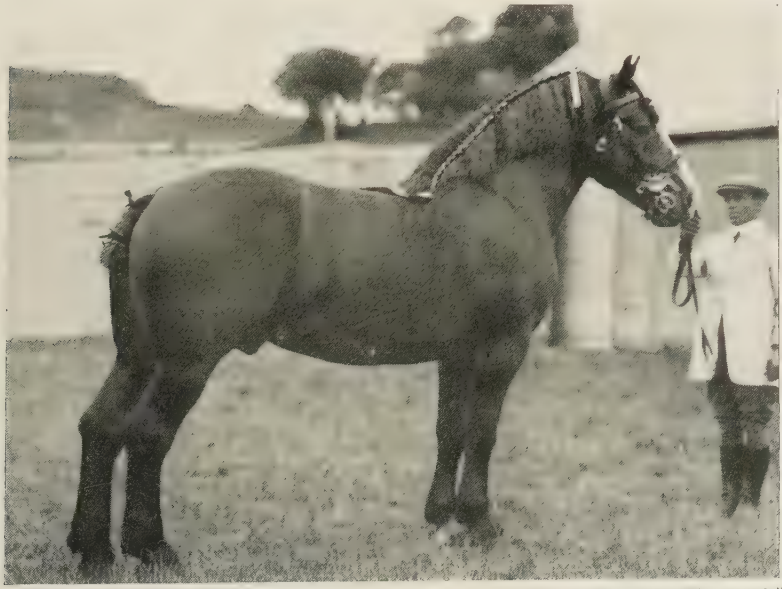
B. Shire Mare, "Pendley Lady"

A. Clydesdale Stallion "Baron's Pride"

B. Clydesdale Mare "Moss Rose"



A. Suffolk Punch Stallion, "Wedgwood"



["*Agricultural Gazette* Photograph"

B. Percheron Stallion, "Quapulet"

the native Shire, Clydesdale, and Suffolk, and the recently introduced Percheron. The Clydesdale is the breed of Scotland and the four northern counties of England, and is the chief of the draft breeds in Ireland. The Suffolk is native to East Anglia and has only recently spread beyond the borders of this province. The Shire is found throughout the rest of England and Wales, excepting only mountain and moorland districts.

The Shire (Plate XXIX.) is regarded as the direct descendant of the Old English War Horse, or Great Horse. This latter was derived partly from the horses that existed in Britain before the Roman invasion, partly from heavy horses that were introduced at various times, chiefly from Flanders. In olden times the Great Horse was valued for his ability to carry the immense weight of armour, etc., of the mounted knight, and various kings of England, from John to Henry VIII. were at considerable pains to maintain or increase the size and quality of the breed. The use of horses for agricultural purposes is comparatively recent, for till the seventeenth century the bulk of farm work was done by oxen.

Careful and systematic breeding of Shires has been carried on since the latter half of the eighteenth century, and some modern pedigrees go back a hundred years. In the days before the formation of a breed society (1878), there was a good deal of variation in type from one district to another, but the breed has been levelled up by continuous interbreeding of the local variations. Of the early Shires it may be said that many were weighty and powerful animals; but upright pasterns and steep narrow hoofs, a want of quality in bone, and unsoundnesses like sidebone were common faults. The aim of the Shire breeders has been to eliminate these defects, while preserving or even increasing the size and weight. The strict veterinary inspection of all animals competing at the shows of the Shire Horse Society has had a very beneficial effect. During the last two or three decades the amount of feather has been very much increased, but few authorities, outside Shire men themselves, regard this as an improvement.

The modern Shire is probably the weightiest of all horses, though the Belgian is sometimes regarded as first in this respect. Mature stallions of the best class, measuring generally 17 hands or over, commonly reach a weight of 20 cwt. when in show condition. The head is heavier and coarser than in other British breeds, and the eye is smaller. Typically, the back is short, wide, and very strong; the ribs both deep and widely sprung, giving a middle of great capacity; the quarters very wide and powerful, but often somewhat short and drooping. The fore-arms and thighs are of great size, and the bone should measure at least 11 in. below the knee and 12 in. below the hock—the larger the better, so long as it is clean and flat. The pasterns are of moderate length and preferably well sloped. The feet are now generally of good size, wide at the heels and open at the hoof head. The feather is long and straight, rather strong in quality, and in the modern show type is very abundant, extending round the sides of the leg. Curly or woolly feather is regarded as objectionable. Common colours are bay, brown, and black, with grey, chestnut, and roan less prevalent. The mare, apart from her smaller size and the feminine character in her head, is relatively longer in body and shorter legged than the stallion. The temperament of the Shire is commonly very docile, sometimes phlegmatic. In general the animal gives the impression of great strength and massiveness. He is an excellent feeder and has great endurance on slow work. The movement is sometimes cumbrous, and the hind action rather stilted.

The Shire, while fairly popular in many foreign countries, has not on the whole competed very successfully with other draft breeds. The criticisms, *e.g.* of American horsemen, are that the breed is lacking in speed and agility, that its wearing qualities are not of the best, and that the feather is far too abundant to enable the animal to work well under muddy conditions. The Shire, so far as concerns the farmer, is essentially a breed for heavy land, and in cities for the heaviest sort of dray work.

The Clydesdale (Plate XXX.) may be said to have had

its origin, during the first half of the eighteenth century, in the interbreeding of the native horses of the Upper Ward of Lanarkshire with colts introduced from England; some at least of the latter were of Flemish breeding. The most famous of the pioneer breeders was John Paterson of Lochlyoch, who about 1715 introduced from England a black Flemish stallion which has been regarded as the foundation sire of the breed. The earliest horse to which pedigrees can now be traced is "Glancer," foaled about 1810, and probably descended, in the female line, from the Lochlyoch stud. Occasional crossing with Shires was done up till about 1890, and a good many three-quarter-blood Clydesdales, with the Shire cross, are entered in the earlier volumes of the *Stud Book*. Many breeders believe that the separation of the breed from the Shire was a mistake, as the original differences were not very marked. The two breeds have, however, steadily drifted apart in many of their characters, and the differences between modern show representatives are rather striking.

The Clydesdale is similar in height to the Shire, the stallion being 17 hands or over and the mare about 16·2. The general build, however, is less massive, the legs being proportionally longer, and the body neither so deep nor so wide. The head shows more quality and refinement, the eye being larger and the muzzle finer. The neck is rather longer and more crested, the head more gaily carried, and the shoulder has on the average more slope. The back is more frequently faulty than in the Shire, being sometimes too long, sometimes hollow, and sometimes rather bare of muscle. Flatness of rib and shallowness of heart or belly are commoner faults. The quarters are usually longer and more level, but narrower when viewed from behind. The arms and gaskins are not so large and are shorter in proportion to the length of the cannon. The bone of the Clydesdale is much smaller, but is harder, flatter, and cleaner, and the feather, which is more silky in quality, is confined to the back of the leg. The pasterns are longer and have more slope, the feet are relatively larger

and wider, but with a more frequent tendency to flatness. The Clydesdale, as a breed, is very free from leg troubles like grease, side-bone, ring-bone, navicular disease, etc., and the average working life, particularly when tested against other breeds on paved streets, is exceptionally long. The breed is also remarkable for its straight, free, and close movement, and shows great agility and cleverness in handling loads. In general it may be said that the Shire excels in weight and strength, and in endurance; while in speed, agility, and wearing qualities the Clydesdale is pre-eminent. The temperament of the Clydesdale is more mettlesome and nervous than that of the Shire; he is more troublesome to break, and requires more horsemanship on the part of his driver. Another point of difference is that the Shire matures at a much earlier age than the Clydesdale, so that the difference in weight is far more marked at the yearling or two-year-old stage than in aged animals. Clydesdales are of all the ordinary colours, bay and brown predominating, while chestnut and grey are rare. White faces and legs are almost constant features, and splashes of white on the belly, or white hairs irregularly mixed throughout the coat, are becoming increasingly common.

The Clydesdale is a common draft breed in Canada, New Zealand, Australia, the United States, and many other countries. Broadly speaking, however, it is less popular than the Percheron. The chief defects of the breed, as urged, *e.g.* in the United States, are its tendency to flatness and shallowness of rib, and narrowness of build, with a consequent inability to keep in condition when exposed to heat or cold or subjected to severe work or scarcity of food.

The Suffolk (Plate XXXI. A) is the least numerously represented of the three native draft breeds. It has been recognised as a distinct local type for several centuries, but some infusion of trotting blood was made over a hundred years ago. The average size is 1 or 2 in. smaller than that of the Clydesdale or Shire, but the weight is not notably less than that of the Clydesdale. The general build is thick, wide, and low set. The ears are rather short, the neck crested, the

chest deep and wide, the barrel large, the ribs well rounded and the quarters wide and heavily muscled, though often rather steeply sloping. The bone is rather light, but not more so than in many modern Clydesdales. The legs carry practically no feather. The pasterns are rather short and upright, especially the hind ones. The feet still show some tendency to flatness, though the breed has been greatly improved in this respect. The Suffolk is active, but the movement is not so straight and true as in the Clydesdale. The colour is some shade of chestnut, with frequently a white spot or blaze on the face and a white hind foot. The outstanding merit of the Suffolk is his constitution. When well fed he puts on a great reserve of fat, and he is easily kept. On ordinary work he can go long hours without food, and stands exposure and scarcity very well. In draft he is remarkably steady and resolute, and he lives and works to a long age. The mares are exceptionally regular breeders. The Suffolk was long in obtaining recognition outside his native district, but during recent years a number of studs have been established in other parts of England, and a considerable export trade has sprung up.

The Percheron (Plate XXXI. B) derives its name from the old French district of La Perche, lying within a radius of some forty miles from the town of Nogent-le-Rotrou, situated about a hundred miles south-west of Paris. The breed contains a good deal of the same blood as the other draft breeds, but was influenced to a considerable extent by the introduction of Eastern (Arab) blood. In coaching times the Percheron was used chiefly for road work, and its evolution into a heavy draft breed has occurred since the widespread development of railways. Its main characteristics may be summarised as follows :—

The height averages 16·2 for stallions and 16 hands for mares. The weight is rather great in proportion to the height, but even by this measure the Percheron is perhaps the smallest of the heavy draft breeds. The head is rather lean and shows a good deal of breeding. The neck is highly crested and the shoulder long and oblique, the chest deep

and wide. Width and strength of back and roundness of rib are very striking characteristics, but the depth of back ribs is not so uniformly good. The quarters are wide, but often short and generally rather steeply drooping, the tail being set on low. The bone is fairly hard and fine, though somewhat round, and the legs are free from long hair. The pasterns are somewhat short and upright, and the feet rather small, but shapely and very sound and durable. The hind leg has often too much "set"—*i.e.*, is too crooked—to please the eye of British judges, and the hock is often lacking in breadth and is too round and fleshy. The movement is sharp, with rather high knee action at the trot, but the front action is not as straight as could be desired. The temperament is very good, docile, yet active and willing. The common colours are grey and black, with bay and brown rare. The Percheron is the favourite draft breed in the United States, where it owes its popularity to its clean legs, its quiet temperament, good constitution, and its high power of endurance on rather fast work. Importations of pure bred Percherons into Britain were of no importance until 1918; but since that time a considerable number have been introduced, and the breed has made progress in public favour.

Horse Breeding.

Breeding animals should be chosen primarily for individual merit, and should preferably be of pure breed and of good pedigree. Continued and indiscriminate crossing should always be avoided, as it gives a greatly increased chance of "misfits." In the breeding mare, quality, trueness to type and roominess of body are more important than size (height). Freedom from any hereditary tendency to unsoundness is most important. The list of diseases that are held as disqualifying stallions from registration under the Horse Breeding Act includes cataract, roaring or whistling, bone spavin, ring-bone, side-bone, navicular disease, shivering, stringhalt, and defective genital organs.

Fillies may be mated for the first time either at two or

at three years old. The question whether it is advisable to breed at the earlier age must be answered according to circumstances—according to the animal's size and condition, and whether it is desired that she should make the fullest growth of which she is capable. Colts at two years old may serve a limited number of mares, generally not more than a dozen. Three-year-olds should be restricted to about sixty and aged horses to about eighty. Much, however, depends on the individual characteristics of the stallion, on his constitution and the effectiveness of his services.

The period of gestation averages rather more than eleven calendar months, and varies quite commonly as much as a fortnight either way. The first heat occurs about ten days after foaling, and œstrum recurs at fairly regular periods of twenty-one days until conception occurs or till the autumn; commencing again, in the barren animal, earlier or later in spring according to food conditions, etc. The duration of the period of heat is about five days, but varies considerably. The foaling season may be at any time between January and September. With Thoroughbreds, where age is counted from the beginning of the year, and where two- and three-year-olds are very often trained and raced, it will obviously be advantageous to have the foals early, and most are dropped between January and March. For ordinary farm horses in this country the most generally convenient season is April to June, since this entails a minimum of housing and attention for the young animal. In countries where summer work is heavy and winter work very light, it is sometimes arranged to have a proportion of the foals dropped in autumn.

In general the fecundity of the mare is far below that of other domesticated animals. An occasional animal conceives regularly, year after year, at her first service, but it is far commoner for mares to "come back" to the stallion several times, and the proportion barren in any one year may frequently reach 40 or 50 per cent. The proportion of conceptions depends partly on the male. Some stallions will "settle" 80 per cent. of their mares while others, under

identical circumstances, will beget very few foals, and a small proportion of apparently normal animals are almost or quite sterile. To ensure good results the stallion must be carefully fed on a good mixed ration, should not be too fat at the commencement of the breeding season, and should have regular exercise during the idle part of the year. As regards the mares, those at grass are more likely to conceive than those kept in stables and on dry feeding. Mares that are on hard work and lean, and on the other hand such as are overfat, are much less likely to conceive than such as are in natural thriving condition. Twins are rare and are not wanted, since they are generally undersized, even when mature.

Ordinary farm mares are generally required to work regularly during the greater part of the year. It is only when the prospective value of the foal is very high in proportion to the cost of maintenance of the mare, that breeding, in itself, is likely to produce a profit. Provided that the mare is in the charge of a skilled and reasonably careful horseman, she may do all classes of farm work during the first six or seven months of pregnancy. In the latter part she should not be put between shafts, and should be excused from any exceptionally heavy jobs, but may continue to work in chains right up to the time of foaling. It is a serious mistake to rest the mare for the last few weeks, if this entails shutting her up in a box and leaving her without exercise; but if it is possible to turn her out to grass she may go idle without taking harm. The approach of parturition is indicated by a gradual slipping or relaxation of the muscles about the tail head, and a swelling of the udder; generally some two days before foaling a waxy secretion will appear on the ends of the teats. As the time approaches the mare should be placed at nights in a roomy box, and after the appearance of the wax should be kept under close observation. The period of labour is generally short, often less than an hour, and false presentations are comparatively rare. Retention of the cleansing is more dangerous than with other animals.

Some patience is frequently necessary in getting the foal to suck, but interference should be as long delayed as possible. After foaling the mare should have laxative and nutritious foods—bran mashes, oatmeal drinks, and clover hay. After two or three days, if the weather be genial, mare and foal may begin to go to grass for a short period, which period is extended day by day, until after two or three weeks they may be left to lie out at nights. In the case of foals born early in the year, exercise should be regularly given until the weather conditions permit of the animals being turned out. When the foaling falls in summer excellent results are often obtained by turning the mare into a clean and sheltered paddock and allowing her to remain out altogether. Where foaling boxes are used they must be thoroughly disinfected for each new case, and must be kept clean.

After foaling the mare should be left idle for at least a month, and may be so left with advantage until the time of weaning. When work is pressing she may be given light jobs, but should not be overheated, nor kept apart from the foal for more than two or three hours at a stretch. If occasionally the mother should be put to severe work or overheated, some of the milk should be drawn by hand before the foal is allowed to suck. The age for weaning may be about four months, or up to six months if the mare is not required for work. The separation should be complete and final; the foal must be closely and securely confined out of hearing of the mare, and the latter should be put into regular work in order to dry off her milk. After three or four days the foal may go back to pasture, preferably with a companion.

If weaning has occurred fairly early in the year, and if good pasture is available, no additional food will at first be necessary in order to keep the weaned foal in thriving condition. Backward animals, or such as have been weaned at an early age, will benefit greatly from a daily mash of bran and crushed oats soaked with separated milk. As the season advances and pastures get bare and less nutritious the foal should get one feed per day, and later, during the

winter, two. A suitable ration for midwinter might be: crushed oats, 4 lb.; bran, 2 lb.; and chaffed hay, 4 lb.—fed either dry or slightly damp and divided into two meals. During periods of frost and snow a little long hay may be thrown out in the field, and many breeders give two or three swedes a day. The foal should be out, whatever the weather conditions, for some part of each day, but should, except in mild districts or in sheltered situations, be housed at night in a freely ventilated box. With the return of grass in spring, hand feeding may be discontinued, and in April or May the animal may begin to lie out. This system of course supposes that a considerable area of pasture is available; pasture is not absolutely necessary but is of distinct advantage. Failing grassland the foal should have a large open yard attached to its box, and must have more hay or other bulky food than is allowed in the ration suggested above.

Castration is generally performed at a year old, or as soon thereafter as the weather is sufficiently mild. Very warm weather should be avoided. The operation involves more danger than with the other species of farm animals, but is no less necessary, although some individual stallions, notably Percherons, work fairly well. No one but a skilled veterinary surgeon should be trusted to carry out the operation. Apart from this the only special attention necessary is to the feet. These should be kept well rasped down so that the frog rests on the ground, otherwise the feet will become long and narrow, and an undue strain will be put on the pasterns. On ordinarily soft land the feet will require to be dressed at intervals of four or six weeks.

Summer pasture for young horses should not be of the rich fattening type, since on such the animal is liable to get too heavy for its legs and thus loose activity and freedom of movement. Young horses grow and thrive best when they are given a wide range of moderate pasture, and when they are running with other stock, preferably cattle. When kept by themselves on a small area they graze very irregularly,

and are also much more liable to suffer from intestinal worms. Only Thoroughbreds are normally given grain (oats) while on summer pastures, and then only to hasten growth for early racing.

During the second winter, if fair rough pasture be available, hand feeding may be confined to a shorter period—say, January to March—and the ration may be lighter and less concentrated. Six pounds of grain, with a similar amount of hay, may ordinarily suffice, but the quantity must depend on the animal's condition and the climate. In no case should the animal be made fat, and it will usually be all the better if it reaches the spring in distinctly lean condition. During the second summer ordinary pasture will again suffice.

The usual age for **breaking** the farm horse is two and a half years. Some Shires are put to work at two, and Clydesdales, in breeding districts, or where the winter work is light, are often left till three. In any case the whole process should not be left until the animal is of age to start work. As a young foal it should be made to understand the use of the halter, and that there is no means of escape from it. This first lesson may involve a severe struggle. Thereafter it should be gradually accustomed to be handled, to have its legs lifted, etc. When these processes have not been gone through at an early age, the preliminary "gentling" of the grown animal is much more difficult.

The first stage of the breaking proper is to put on harness and lead the animal about, in order that it may lose the sense of irritation and alarm at the contact of the tackle. Thereafter it should be driven on long reins, for an hour or so at a time, until it answers to the bit; two or three lessons will generally suffice. Care must be taken to avoid damage to the mouth, as repeated bleeding, even if slight, causes the "bars" (on which the bit rests) to become insensitive. These lessons may be combined with or followed by training in draft, which is best started by means of men pulling against the animal on long rope traces, the pressure on the shoulders being applied gradually while the animal is in motion. Finally, it may be harnessed along with a steady but active

horse in the plough, with at first an additional leading rein and a man alongside. Work in shafts should be postponed for a few months. Judgment must be exercised in the matter of the time to be allowed for each stage. Some animals can be put almost straight into work, while others may require a week or two of preliminary training. Fractious animals should be trotted round on the end of a rope, preferably on heavy going, such as fresh ploughed land, before each lesson. This preliminary exercise should proceed until the animal is tired enough to be amenable to discipline but not, except in extreme cases, to the point of exhaustion.

There is a good deal of variation in the methods by which the necessary horse-flesh is maintained on the farm. In the remoter country districts many farmers work their animals only until they are five or six years old, at which age they are sold for dray work in cities, or to other farms where there is a large amount of road and cart work to be done. Provided that skilled horsemen are available for breaking and training, this scheme has the obvious advantage that the average value of the horses may be expected to appreciate during their period of farm work. If the whole working life is utilised a good animal, barring accidents, may be expected to remain fit for regular work until the age of from fourteen to eighteen years, after which it may fill the post of "odd horse" for two or three years more. When all things are allowed for, the average working life will not greatly exceed ten years, say from three to thirteen years old. The average life is influenced largely by the skill shown in feeding and general management, but also on the amount of road work that falls to be done and, naturally, on the breed and individual character of the horses used.

Feeding of Work Horses.

In Britain oats and hay form the usual basis of the ration for work horses; and provided the oats be sound and not too new, and the hay be clean and hard, there are no other feeding stuffs that are so wholesome or so generally

useful. Of the various hays, timothy, rye-grass, and good meadow hay are all very satisfactory. Clover is less good, since it is too laxative for animals on severe work. Dusty hay is objectionable, in that it spoils the "wind"; and mouldy or ill-got material should be avoided if possible. For the winter months, when work is often irregular and the day is short, oat straw is often substituted for hay, and in such circumstances forms a useful fodder, though it is too low in nutritive value for animals on hard continuous work. In northern clay-land districts bean straw is used as a partial or even complete substitute for hay throughout the year. The taste for it is somewhat slowly acquired, but ultimately many horses come to prefer it to other fodders. It is less nutritious than hay, and the concentrated ration must be correspondingly heavier.

Of concentrates other than oats, maize is quite largely used, chiefly because it is often proportionately cheap. Three pounds give the same energy value as four pounds of oats. If it is to form a large part of the ration it must be introduced gradually, and it gives the best results when mixed with oats and dry bran in order to lighten it. Barley makes a good horse corn, but wheat is unsatisfactory, being liable to produce colics unless fed with care. Rye is worse. Beans are good, up to a moderate proportion—say one-eighth of the grain ration. Crushed linseed, or linseed-cake is an excellent conditioning food for animals that are run-down, but it is too laxative to be fed in quantity to animals on severe work; 1 or 2 lb. of the former or 2 to 4 lb. of the latter is a common amount to feed daily. Molasses or one or other of the various molasses foods is sometimes added, as an appetiser, to the grain ration and is useful for shy feeders. A bran mash in place of the usual evening feed of grain is given on Saturday nights as a matter of routine in most stables in order to prevent, by its mild laxative action, the possible ill-effects of the following day's idleness. It is specially important when work during the preceding week has been continuous and hard.

On farms where summer work is not very heavy, the

work horses usually run at grass, and are given a feed of 5 or 6 lb. of concentrate for each half-day that they work. They must be stabled and "hardened up" before the regular work of harvest commences.

The amount of the daily ration must be determined according to the size of the animal and the amount and severity of the work being done. A full-sized active heavy draft animal, on hard and continuous work, will require quite 20 lb. of oats, or its equivalent in other grain, per day, along with nearly the same weight of good hay. The following are examples of rations for a farm horse of average size—say 1400 to 1500 lb. live-weight.

Light or Intermittent Work.	Medium Work.	Continuous Heavy Work.
12 lb. oats.	16 lb. oats.	10 lb. maize.
8 „ hay.	16 „ hay.	5 „ oats.
10 „ oat straw.	10 „ swedes.	5 „ bran.
20 „ swedes.		14 „ hay.

The actual expenditure of energy depends to a greater extent on the speed at which the work is performed than on the hours worked or the pull.

In periods of complete idleness the grain ration must be severely restricted, as many ailments arise from over-feeding at such times. In general, of course, the rations must be adjusted to meet the individual requirements of the animals, the object being to keep all in good hard condition, but not to make them fat.

As regards the preparation of the food, the grain should be bruised if possible, a proportion of the fodder should be chaffed, and grain and chaff fed together. This has the double object of preventing the animal from bolting the grain and of saving part of the work of mastication. Some horsemen give the whole of the food in the form of a mixed chop, but the consensus of opinion is that some long fodder is advantageous. The old practice of boiling or steaming roots, grain and chaff, and feeding the mixture in the form of a warm slop, had nothing to recommend it, and has been very generally abandoned. Feeding should

be done not less than three times a day, and at least a full hour should be allowed both for the morning and for the mid-day meal. Water should be given freely four times a day—always before feeding, or, at least, not immediately after a meal. Exception should be made only in the case of an animal in very overheated and overtired condition; in such cases the horse's thirst should be quenched gradually, with half a bucketful of lukewarm water at short intervals until he is satisfied.

Horses at work should be thoroughly groomed once a day. Legs should not be washed often, but should be allowed to dry and be then brushed out. In periods of idleness during winter an hour's exercise should be given at least every second day. Exercise is the more necessary if the animals are suddenly thrown idle after a spell of hard work.

Shoeing should be done at intervals of six or seven weeks, or oftener in cases where the feet are thin or liable to break. New shoes are of course not necessary on all occasions. At the onset of winter, but before the coat is fully grown, farm horses should be clipped "trace high"—*i.e.*, the coat is removed only from the chest, belly, and thighs, while the head, neck, back, quarters, and legs are left untouched. This plan allows the horse to keep reasonably cool at work and yet leaves the natural protection against rain on the one hand and mud on the other. The end of November is generally a suitable time to clip. The stable should have ample head room, and should be well ventilated and well lit. Stalls should be 6 ft. to 6 ft. 6 in. wide, and the length from manger to back wall should be about 18 ft. Overhead racks are undesirable.

Careful routine management must be accompanied by a close watch over individual animals, and early attention must be paid to common ailments such as sore shoulders, "weeds" (lymphangitis), colics, colds, and lamenesses. Horses that are in lean and unthrifty condition should have their teeth examined and filed if necessary. Intestinal worms are

another frequent cause of a failure to thrive. A supply of rock salt in the manger will generally help in the maintenance of health.

Asses and Mules.

Donkeys are used in this country for farm work, but are generally to be found only on the smallest class of holding, for which they are rendered suitable by their small food requirements. Abroad their chief commercial value lies in the production of sires for mule breeding. The breeds that are held in the highest esteem for this purpose are the Catalonian (Spain) and the Poitou (France). The former has unusually good symmetry and action and reaches a height of 14 to 15 hands; the latter is a breed of great weight and substance and large bone, and is generally from 15 to 16 hands high. The females are about two inches smaller in each case. Other well-known breeds are the Maltese, the Majorca, and the Andalusian. Mules are preferred to horses, both for farm and city work, in warm climates. They are bred in great numbers in most Mediterranean countries and also in the warmer regions of both North and South America.

BOOK IV

FARM ORGANISATION AND MANAGEMENT

CHAPTER I

LAND AND ITS EQUIPMENT

It has often been pointed out that technical skill, whether in the growing of crops or in the breeding and feeding of stock, does not of itself ensure financial success in the farming business. Such success depends, in equal or perhaps in greater measure, on what may be roughly termed the business capacity of the farmer. And while it is true that this business capacity consists to a certain extent of qualities that hardly admit of scientific treatment or definition—such, for example, as ability in driving a bargain or in the management of men—yet it remains possible to state a number of principles that help towards the organisation and running of the farm as a business concern. It is these principles that form the subject-matter of the present section.

Throughout the history of agriculture the importance of economic considerations has steadily increased. In the earliest stages there was little or no specialisation of industry and little or no commerce. The husbandman fashioned his own implements and built his own house. He produced his own food stuffs, textiles, building materials and fuel, while his women folk baked, brewed, and spun. Under such circumstances the farmer based his organisation on the requirements of his own household, beyond which he had no concern. In process of time, however, he handed over some of his old activities to the smith, the wright, the miller,

and so on, and in return he had to increase his production of food stuffs and other raw materials beyond what he himself required. Also, as time went on and commerce developed, farming itself became specialised up to a point, some men turning to wheat, others to cattle breeding or wool growing; and now, in the modern community, the farmer uses but a small fraction of his own produce, and satisfies his needs chiefly through the exchange of goods for money and of money for goods. In one way this change has made for simplicity in the farming system as it has also assisted towards economy in production. The farmer need no longer consider the particular requirements of his household, except in so far as these can be economically met by home production. In the main his object becomes the simple one of the highest possible net financial return.

In other respects, however, the organisation of the farm has become much more complex and difficult. It is comparatively easy to predict the requirements of a household; much less easy to weigh up the various demands of a large community and to balance these against probable supplies. Before the development of trade the farmer had no need to look beyond his immediate locality, whereas with world competition and world markets he must keep constantly in mind the conditions in many parts of the globe, and must confine himself to the production of commodities that can, under his particular circumstances, be produced at competitive prices.

The agents that are used in agricultural production are land, capital (including buildings and other "improvements," implements and machinery, animals, seeds, manures, etc.), and labour. The land may be utilised in various ways, as, for instance, arable, pasture, meadow, orchard, woodland, etc. Capital and labour may be applied in varying measure, intensively or extensively as we say. Produce may be marketed direct, *e.g.* wheat or potatoes, or may be converted into animal products and marketed at second hand, *e.g.* roots and straw. Sometimes material must be purchased to permit of the profitable disposal of home produce, as cake to allow of

the utilisation of straw. In general it will be found that the economical use of land, labour, and capital can only be effected by the dovetailing together of several distinct departments. Only rarely will it happen that a single branch like wheat production or potato growing, sheep breeding or cattle grazing will constitute in itself a complete and economical system, leaving behind no by-products that are worth utilising. As a rule, efficiency cannot be attained without complexity.

How to use land; how to equip it; what crops to grow and how to dispose of them; what labour to hire and how to employ it—all to the end of the maximum net profit, and having regard to all the local conditions—such is broadly the problem of organisation.

Land.

Land, the first essential agent of production, varies in quality and in value. These depend not only upon the original nature of the soil, climate, etc., but also upon any improvements in its condition or surroundings that have been made by human agencies in the past. The measure of its value is the true or economic rent, *i.e.*, the income it is capable of yielding over and above the usual return on capital and the usual rewards for labour and skill in management. The broad theory of rent is that the poorest or the least accessible land that will be used for agriculture is such as will only just repay the application of capital and labour, but will leave no margin. Such land may be said to be "on the margin of cultivation." Any land that is more fertile, or more accessible to markets, will produce a return over and above the current return to capital and labour, which surplus constitutes "economic rent." The rent that a piece of land will produce cannot, however, be determined without reference to the amount of capital and labour applied to it. The kind of land it is just worth while to use, and the degree of intensity of cultivation that it is worth while to apply to land within the margin of cultivation, will change with changing economic conditions. Thus in the middle of last century much poor and heavy land in Essex was

growing corn, while thousands of square miles of prairie, capable of growing better crops with less labour, were lying idle. A rise in wages coupled with a lowering of transport costs reversed the position and the prairie lands were broken up while Essex farms fell derelict. But later, owing in part to the growing world demand for wheat and in part to the development of the London milk market, these farms again came within the margin of cultivation.

Fertility is a composite conception, implying an estimate of the quantity and quality of produce that the land is capable of yielding, in relation to the amount of human effort expended on it. It depends on a great variety of circumstances, such as the presence of plant foods and the absence of plant poisons in the soil; the behaviour of the soil towards moisture; its ease or difficulty of cultivation; the amount, regularity, and seasonal distribution of the rainfall; the temperature conditions, sunshine, etc. It will be obvious that there can be no permanent estimate of fertility, because progress in agricultural technique affects the possibilities of various types of land in very different ways. Thus, for example, the discovery of the use of lime or of potash; the invention of tile drainage or of tractors; the introduction of the potato or of wild white clover; all these and many other steps in the progress of agriculture have brought about changes in our estimates of the relative values of different lands. Not only so, but estimates of fertility change from time to time and from place to place with changing economic conditions, as witness the Down tops and the Fens in prehistoric as compared with modern times. Now the Fens are incomparably more fertile, yet we know that the high, thin, chalky soils were the first to be brought under cultivation, while the fen lands were almost the last. Or compare the values in different localities of dry, sandy, chemically poor soil and of chemically rich heavy clay. Near London the Greensand is very intensively cultivated and highly valued, while the heavy soils are comparatively neglected. At a distance from markets the greensand becomes practically worthless, while the clay loses

but very little of its value. In these days, with rising wages and falling prices for chemical manures, light and hungry but easily tilled soils are becoming more valuable while chemically rich clays, on account of their high tillage costs are diminishing in value; but a revolution in tillage methods, whereby cheap power could be efficiently applied to the land, might swing the balance in the opposite direction.

Under nature every piece of land has a certain type of flora, the resultant of the soil and climatic conditions. Thus we may distinguish between steppe or prairie, moorland, natural forest of various types, and many others. Moreover, each type of flora supports a particular type of fauna; usually, so long as soil and climatic conditions remain the same, the flora and fauna tend to remain constant, though in other cases cycles of vegetation—what have been called natural rotations—accompanied by corresponding cyclic changes in the animal population, are found to occur.

Agriculture, in the widest sense, may be said to include all schemes that are employed by man in order to increase the usefulness to himself of the plant and animal life that the land supports. Such interference may be slight, consisting, for example, of nothing more than the aiding of useful species of plants and animals by attacking their natural enemies (game preserving, forest conservation), whereas in its final stage agriculture aims at the complete suppression of the greater part of the natural flora and fauna (weeds and pests), and substitutes one or more selected species, which are modified and cared for in order to develop their maximum usefulness. The larger the human population to be supported and the greater its wants, the greater will be the extent of our interference with nature, *i.e.*, the more intensive will agriculture become.

Lands are classified, from the agricultural point of view, according to the product for which they are specialised, thus:—

1. *Game and Fishing Preserves.*—Wild animals under some degree of protection.
2. *Forest.*—Trees grown for timber, bark, etc., where utilisation involves felling.

3. *Orchards and Plantations.*—Trees or other perennial plants for fruit, leaves, latex, etc. where utilisation does not involve felling.
4. *Garden and Nursery Lands.*—Plants requiring or repaying highly intensive treatment, individual care, etc.
5. *Farm Lands*:—
   (*a*) Pasture.—Perennial herbaceous plants, grazed;
   (*b*) Meadow.—Perennial herbaceous plants, mown;
   (*c*) Arable.—Plants propagated annually.

The boundaries between these different classes are of course not hard and fast. Thus between farm and garden, garden and orchard, etc., there is an insensible gradation among cultural schemes. Moreover two purposes may be combined, as in the case of hill grazings that are also grouse moors, or orchards or woodlands that are also grazings. Again among farm lands we find many that are worked on a system of alternate grass and arable husbandry. The first problem of organisation is to allot the land to the particular purpose for which it is best suited, *i.e.*, to whichever mode of utilisation is likely to produce the largest net return. Taking the various types in the following order:—

Game, from the fact that it is kept in the wild state, is capable of yielding only a very low gross return measured in actual produce. Hence it can only become the most profitable product either where land is of very little value for other purposes (*e.g.* mountain or heath), or where, in wealthy communities, there are people who are prepared to pay relatively large sums in order to gratify their desire for sport. Generally the two conditions must occur together before any considerable amount of land will be set aside exclusively for game—*i.e.*, there must be both a supply of low-valued land and a considerable demand for sporting rights.

The preservation of game on land that is being used for another purpose—whether forestry, agriculture, or horticulture—always reduces its value for such other purpose; moreover, game animals, since their feeding is not under

control, are capable of doing an amount of damage that is quite out of proportion to the amount of food they consume —*e.g.* when they attack crop plants in the seedling stage. Nevertheless, where there is a good demand for sporting rights, a certain amount of game may pay, *i.e.*, may add to the net value of the land. The amount that is permissible depends on the system of utilisation that is being applied. In general, the more intensive the cultivation the less place is there for game; thus on mountain grazings game is often exceedingly profitable; on the better sort of grasslands, in established woodlands, and on the less intensively worked types of mixed farms it may be quite in place, whereas under intensive arable conditions, and still more in gardens and nurseries, it must be reduced to a minimum.

Forest Lands, of which timber is the chief product, are dealt with in various ways, and produce forests of many different types. One outstanding feature is of course the long period that is required for trees to mature, or even to reach such a size as to enable them to be utilised at all. Forty, eighty, or even considerably over a hundred years are common lengths of rotation. This implies, almost unavoidably, a relatively high capitalisation; for even if we suppose a small figure for planting, etc., and a low annual rental of the land, the initial and current charges, lying out at compound interest over such periods, eventually grow to very large sums. Again, the produce of "cultivated"—*i.e.*, of planted and tended forests—has still to compete with that of natural forests in various parts of the world, so that the gross income cannot reach a very large figure, although, as the world's forest reserves become depleted, the price of timber in relation to the general level of prices will very probably rise. But under existing conditions these two facts taken together must lead to the conclusion that it is only where land has a very low agricultural value that forestry can be an economical success. If, for example, a piece of land is worth, as grazing, five shillings an acre of annual rent, it will be doubtful, even if it is fairly well suited for afforestation, whether forest could give as high a return.

On the other hand is the fact that forest trees have, as compared with practically all agricultural and horticultural crop plants, a very low requirement of soil nutrients. Also, since forest land requires no cultivation, trees can be grown on steep or rocky ground which cannot profitably be tilled. Hence timber can be produced with success on land that is practically worthless for any other purpose. Forests employ relatively little labour and require little equipment, circumstances that give forestry a place under extensive conditions, *i.e.*, where land is cheap in relation to the other agents of production. Timber is costly to transport by land, but cheap to carry by water, so that proximity to rivers, etc., is an important consideration. Trees are more liable than are agricultural and other crops to destruction by wind and fire, and the amount of risk and the possibilities of protection must be taken into account in deciding for or against afforestation.

In so far as concerns particular areas, forestry should be regarded as an alternative to agriculture. There are, it is true, woodlands that have a certain grazing value, but such combined utilisation is rarely economical. The feeding of pigs in forests of oak, beech, Spanish chestnut, etc., is an important exception, making possible the utilisation of a valuable by-product without disadvantage to the forest itself.

If, however, we have in mind not individual plots of ground but large districts, we may find that farm and forest are not alternatives but are the economic complements of each other, *i.e.*, a suitable allocation of land to each will produce a higher average return than could be obtained from either by itself; and this may happen even when the land within the area does not vary sensibly in quality. Examples are to be found in regions where transport is expensive or difficult and where the population has to depend mainly on local produce. Here the farm lands produce the materials for food and clothing, the forest those for house and fuel. Again, in many of the colder parts of the world, agriculture provides employment during only part of the year—the frost-

free period—whereas in forests the greater part of the work, including felling and disposal, can be done in winter. Thus the two industries together can employ labour more economically than could either alone.

Woodlands may also, in certain cases, be properly regarded as minor adjuncts to farms, being maintained for the purpose of producing the quantity of timber necessary for fences and the like. In exposed districts, woods in the form of shelter belts may have a very considerable value to the farmer, and in hot climates trees are useful for the provision of shade for live stock. In such cases timber production becomes a secondary consideration. The provision of cover for game is a further minor use of woodlands.

Orchards, and Plantations other than of timber trees (*e.g.* sugar maple, rubber, coffee, nuts, etc.), resemble forests in so far that they are formed of perennial plants that usually require to stand for a series of years before they begin to yield. They have thus the same general feature of a high capital requirement. The productive stage is, however, usually reached a good deal earlier than in the case of forests; moreover, the yield of the individual trees is sustained over a series of years and tends to remain fairly constant from one year to another. Orchards, etc., also differ from forests, and resemble garden lands, in that the labour requirement—for grafting, pruning, harvesting, curing, and packing of the produce—is high. In most cases cultivation of the soil is necessary or desirable, so that there must be no serious obstacles to tillage; but since this tillage is normally not very intensive, great ease of cultivation is not essential. Many of the products of orchard lands, unlike timber, carry away considerable amounts of manurial substances, so that the soil should generally be chemically fertile. Wind shelter and immunity from frost during the growing season are also important. Capitalisation, current charges and gross returns per acre all tend to be higher in fruit-growing than in ordinary farming, and the yield and quality of the produce are at least as dependent on soil and climate as are those from annual crops or grass. It follows that land suitable

for fruit-growing often commands a rent which could not be paid by the ordinary farmer.

Market Gardens represent what is really the limiting case of the arable farm ; the type of crop, a plant propagated annually and grown in pure culture, is essentially the same, and the chief difference is that the gardener confines himself to those species or varieties which, because of their capacity to yield crops of high value per acre, repay more intensive cultivation and individual treatment, whereas the farmer is restricted to such as are fairly robust growers and can be dealt with by cheap wholesale methods. Many crops, as potatoes, carrots, cabbages, etc., are common to both systems, and many holdings are cultivated on a system intermediate between the two. Most garden produce is perishable, or at least has a maximum value when quite fresh, whereas farm crops and their products can generally be stored for considerable periods and can be handled and marketed in quantity and cheaply. Then also, all garden stuff is used directly for human food, whereas much farm produce is converted by live stock into secondary products.

One outstanding feature of the market garden is of course its high labour requirement. Few farms, apart from the transition type of holding mentioned above, employ more than five or six persons per hundred acres, whereas in market gardens the labour may rise to one person per acre, or with glass, etc., far higher. The capital investment, apart from glass, is not proportionately high, chiefly because the turn-over is so much more rapid.

In respect of physical conditions, the gardener's crops are by definition of a less robust type than those of the farmer. Moreover one of the main objects of the market gardener is to produce, as nearly as may be, a constant supply of fresh material at all seasons of the year. These facts both point to the selection of land so situated that the growing season reaches the maximum length for the locality, and in places where the climate is as mild and equable as possible. Hence in Britain a low elevation, proximity to the sea, a southern exposure, and shelter from winds are all of importance. For

the same reason, the soil should be of a warm early type, *i.e.*, light and well drained. The last point has a double importance, for since a succession of supplies must usually be aimed at, the soil must be of such texture that it can be worked, and a tilth secured, at many different seasons and under many different weather conditions. The heavier the soil, the more is the cultivator restricted as to his time of seeding. Moreover stiff clays, even at the best, can scarcely be got into the state of tilth necessary for the smaller seeded and more delicate of the gardener's crops. Chemical fertility is to the gardener relatively unimportant. Labour costs (with of course the gross value of the produce) are so high that even very intensive manuring involves only a relatively slight addition to the total. At the same time it must be borne in mind that the lightest sands cannot be successfully worked unless organic manures, as well as artificials, are available. Without the former the moisture supply will be liable to fail.

The ultimate form of intensive gardening is of course cultivation under glass, *i.e.*, with both a climate and a soil that are very largely artificial. In this case almost all the physical conditions are under control, and the natural quality of the land loses its importance.

Probably more important than any of the natural conditions is the economic situation of the land, *i.e.*, its proximity to markets and the state of development of means of transport and of methods of marketing. Hence market gardening has tended to become concentrated near centres of population, although in recent times developments in transport have worked towards a wider spread of the industry. It will be obvious that the increase in population of the world will tend towards the increase of garden at the expense of arable farm lands, just as it will cause grassland to be broken up for arable farming.

Nurseries devoted to the propagation of perennial plants (*e.g.* fruit and forest trees) are akin to gardens in their high labour requirement, but are found under a greater variety of soil and climatic conditions. They tend, however, to be

established on the more easily tilled soils, and under the more favourable climatic conditions.

Agricultural Lands include pastures, meadows, and arable fields. If the cultivator allocates a given area for an indefinite period to one purpose or the other, we speak of "permanent" pasture, meadow, or arable, but it will be obvious that no scheme of allocation, if it is to depend on economic considerations, can be truly permanent. Changes in the distribution of population or developments of transport methods may, and frequently do, force the breaking-up of grassland in one area and the laying down of arable to grass in another. Improvements in methods of tillage or in the technical management of grasslands, and many other causes, may have a like effect in one direction or the other. The alternative to such "permanent" allocation of the land is to adopt some scheme whereby the land is put under tillage and grass during alternate and more or less definite periods of years. The three possible systems are therefore: (1) permanent grass (including both pasture and meadow); (2) permanent arable; (3) alternate husbandry; and it is necessary briefly to set down the main considerations that should guide the farmer in deciding for one or the other.

(1) In the first place, the gross return from arable land whether measured in terms of value or in terms of quantity of human food, etc., is higher than from grassland. At the same time the expenditure, including labour costs, capital charges, depreciation, risk, etc., are also higher. This amounts to saying that arable farming is the more intensive system of the two, and will, other things being equal, tend to prevail wherever the land is fertile and of easy access to markets. The less fertile or the less accessible the land the more will it tend to be left in grass. Land that falls below a certain level of fertility, whether owing to a short growing season, insufficient warmth, rain or sunlight, or to chemical or physical deficiencies of soil, will fail to leave any net return under arable farming. Similarly, at long distances from markets, ports, railways, or good roads, land becomes "not worth ploughing." Much of this land that is beyond

the margin (in the economic sense) of arable cultivation, is still capable of paying a rent under the less intensive system of grass husbandry.

(2) The next question is that of the difficulty or ease of cultivation. The expenditure on grassland is not only low, but varies within comparatively narrow limits.[1] In the case of arable fields the expenditure is not only higher but varies, with soil and climatic conditions, within far wider limits. Thus level, free-working soils that are free from large stones and are situated in districts of moderately low rainfall are those which tend to be kept under arable cultivation. Great tenacity of soil, steep slopes, excessive rainfall, etc., all add materially to cultivation costs and so favour the alternative of grass farming. It will be obvious that economic conditions, such as the relation of wages to prices and the possibilities of using labour-saving devices, will also have an important bearing on cultivation costs. These questions are treated in Chapter III.

(3) Apart from the question of tillage costs, the conditions that constitute maximum fertility for grass and for arable crops respectively are different. The most striking difference is in the matter of moisture requirement. The act of tillage itself tends to conserve moisture, so that there is less wastage of water under arable cultivation. Grassland is covered (throughout the year) with a more or less dense herbage, whereas arable ground is unoccupied for at least a part of the year, and is only sparsely covered with vegetation for a further season. Hence the moisture requirement of grass is much the higher, with the result that grass tends to predominate in regions of high rainfall, on the more retentive soils, and for example on river flats, where there is a supply of water from the subsoil. Again, arable crops, most of which are required to ripen, are benefited by dry weather for this process and for their harvesting, whereas with grass, prolonged vegetative growth, which is favoured by continuously moist conditions, is what is wanted. This connec-

[1] The new intensive system of pasture management (see p. 339) is an exception. It is still in the experimental stage.

tion between moisture and cropping is very easily traced if rainfall and cultivation maps of this country be compared. Again, arable crops pass through phases, such as the seedling, the flowering, and the ripening stage when they are liable to suffer disastrous damage from climatic agents like late or early frosts, summer hail, wind, rain, fog, or drought. These may act either directly on the plant or may produce damage by encouraging insect pests or fungoid diseases. Grass suffers relatively insignificant damage from such causes. Hence under very uncertain climates land has very little value for arable purposes and yet may be very valuable for grass.

(4) The "agricultural situation" of a piece of land (*e.g.* its position in relation to other land and its accessibility to the farm buildings) may also prove a determining factor. Thus, as will be made clear below, certain advantages accrue from having a certain area both of grass and arable on the particular farm. Hence in mountain grazing districts one finds small areas of land kept under arable cultivation, not because they are intrinsically suited for this purpose, but only because they are less ill-adapted than surrounding areas. Within the individual farm a limited area of pasture quite close to the farm buildings is a convenience of obvious value. Apart from this the more distant or less accessible fields will tend to go to grass, while the land of easier access will tend to be kept as arable. The question of water supply to grazing stock is another point that must be borne in mind when a scheme of allocation is under consideration.

Regarding the two modes of utilising grassland, it is obvious that wherever there is a definite non-growing season, where anything approaching intensive methods of stock feeding are possible, and where there is no sufficient supply of arable land products, meadows for the provision of winter food are the necessary complement to pastures. Seasons of drought, whether of regular or occasional occurrence, fall to be provided for in the same way. Mowing and haymaking involve a considerably higher expenditure than grazing, so that the more productive of the grasslands will usually be

set apart as meadow. Relative freedom from obstacles is also of importance. Apart from this, lands that are too wet to carry stock, or are unhealthy for grazing animals, will tend to be allotted to meadow.

Very frequently it happens that the most profitable system for a particular farm includes both arable and grass. Apart from the question of the distribution of risks, it is often desirable that a certain quantity of stock should be permanently maintained, *e.g.* dairy or "regular" breeding stock. And in such cases it will generally happen that pasture provides the cheapest summer food, while the winter requirements can be most economically met by arable cropping. In alternate (as opposed to merely mixed) husbandry there is the further important advantage that grassland accumulates nitrogen and humus, whereas tillage exhausts the soil of these very important constituents. Moreover, weight must be given to the fact that temporary grass, at least in the earlier years of its existence, is commonly more productive than permanent grass under similar conditions, although exceptions occur. The broad result is that a given standard of productiveness can be maintained, under a system of alternate husbandry, with a lower expenditure in labour and manures than under a system of permanent division into arable and grass. On the other hand, land under the alternate system requires a measure of double equipment—it must be fenced and supplied with water if it is to be grazed, and for arable purposes it must have roads. Added to this is the additional expenditure for periodic re-seeding with grasses, and the well-known risk of failure that attends the laying down of land to grass. The latter obstacle to alternate husbandry assumes most importance on the heavier soils, on which a suitable tilth for the smaller seeds is difficult to obtain. In reaching a decision for the one or the other system of mixed farming, the one set of considerations must be balanced against the other. If the land of a farm is tolerably uniform in fertility and accessibility, and its soil of fairly uniform texture, and if grass is not too difficult to establish, alternate husbandry

should generally be preferred. If, on the other hand, the land of a farm includes rich and poor, high and low, heavy and light, etc., or if it is difficult to lay down successfully, then a permanent division may be the more profitable scheme.

Capital.—Farm capital includes all the equipment that is necessary to make the land productive. It is usual to draw a distinction between such forms of capital as are practically inseparable from the land—buildings, roads, drains, etc., and such as are readily separable—implements, live-stock, annual crops, etc. Obviously this distinction is not absolute, *e.g.* a wire fence is movable, but the cost of moving it may represent a considerable part of its value; a hill sheep stock is readily movable, but its value in the market may be less than its value on its native grazing. A sum spent in manuring with nitrate of soda is probably recoverable within a year, one spent on slag in perhaps three or four years, and one spent on liming perhaps not in ten or twenty years. The broad distinction is, however, important, especially in countries, such as Britain, where the landlord and tenant system prevails. Here the fixed capital is the property of the landlord, and interest on it is included in the rent, while the movable capital is furnished by the tenant. Questions regarding the quasi-permanent forms of capital are settled by custom, by covenants in leases, or by law.

Landlord's Capital.—*Buildings*, apart from dwelling-houses, comprise stables for work horses, implement sheds, storage accommodation for produce, *e.g.* corn lofts, hay sheds and straw barns, and accommodation for stock. It will be obvious that the amount and quality of the buildings necessary will depend to a large extent on the climate; the longer and the more severe the winter the more commodious and the more substantial must the buildings be. Hence, in the north of Scotland, the capital represented in buildings generally bears a very high proportion to the freehold value of the land, whereas in the south of England the capital so invested is very much less. Again the necessary capacity of the buildings depends on the number

of stock maintained during winter. This is generally far greater on arable and semi-arable than on grass farms, because stock tends to be transferred from the latter to the former in autumn. Thirdly, the accommodation required depends on the type of stock that is to be kept. Thus winter-feeding cattle, dairy cows, and pigs on the indoor system require much housing, whereas sheep, out-wintering store cattle, etc., require little. Since the provision of buildings will often be outside the farmer's province, it frequently happens that he must make his system fit in with the buildings available; if, however, it is within his control he must endeavour to satisfy himself, with regard to any proposed addition or alteration, that there is a likelihood of an economic return on the outlay that would be required.

The following are approximate figures representing the amount of space (floor area) desirable under the various heads:—

Work horses	120 sq. ft. per horse.
Cart and implement sheds	500 „ per pair of horses, or, say, 10 sq. ft. per arable acre.
Dairy cows	65 „ each.
Feeding cattle, covered courts	90-100 „ „
Half-covered yards—covered portion	60 „ „
Root sheds (roots 3-4 ft. deep)	2 sq. yds. per ton stored.
Dutch barns, hay and straw sheds—	
Hay	$1\frac{3}{4}$ cwt. per cubic yard.
Straw	1 „ „
Unthreshed corn	2 „ „

Apart from the question of the amount of available accommodation, which influences the stock-carrying capacity of the farm, its arrangement from the point of view of economy of labour has a large importance. The most important points are connected with the handling of the bulkier materials, such as roots, straw, hay, and dung. With ideal buildings, and with all materials delivered to his hand, a man can attend to eighty or ninety head of fattening cattle, while under the worst the number may be as low as thirty.

The position of the buildings is also a point of importance. This, where the land is of uniform quality, should be as central as possible. In other cases the ideal position is nearer to the most fertile and most intensively worked portions. Access to public roads is also an important consideration as affecting the most convenient point. On very large holdings subsidiary homesteads may be desirable.

Fencing of sub-divisions of the farm becomes necessary wherever grazing and cropping are carried on together; also, on purely grazing land fences are desirable in order to control the movements of the animals and thus to ensure full utilisation of the grass. In general the more intensive the system of grazing the smaller must be the individual enclosures. On the poorer types of grasslands, *e.g.* hill grazings, the erection of fences will often not be justified economically. Fences may be either temporary or permanent.

The cost of fencing per acre (where the shape of field is constant) varies inversely as the square root of the area, *e.g.* if one field is four times the size of another, the length of fence required will be only twice as great, or half as much per acre. Fencing imposes a considerable burden on the land. For example, if we erect a substantial wire fence for 1s. 6d. per linear yard, the outlay will amount to £3, 6s. per acre for 10-acre square fields, or to £1, 13s. per acre for 40-acre square fields. These sums will represent annual charges, including interest and upkeep, of perhaps 5s. and 2s. 6d. per acre respectively.

The number of fields, in the case of farms run on a system of alternate husbandry, cannot be less than the number of years in the rotation, *i.e.*, a four-course farm must have at least four fields, and a seven-course farm at least seven fields. It is often necessary, in the interests of efficient management of the temporary grasslands, and especially when several different classes of stock have to be provided for, to increase this number, say two or three fold. Very small sub-divisions such as exist in many parts of England lead to great inconvenience in working, as well as to a very considerable loss in the total cultivable area.

Fields should be rectangular, unless natural obstacles, etc., impose some other shape; irregular shapes involve a very considerable loss of time in cultivation. For large fields (say 30 acres or more), square is generally the most convenient shape. Smaller fields should preferably be oblong, in order to give a longer furrow and so more economical working.

Roads are a necessary adjunct to the arable farm; the type necessary is dependent on the nature of the traffic they have to carry, particularly on the amount of heavy winter carting. Thus if roots are to be carried off a field and farmyard manure carted on, a tolerably well-built road is essential, whereas if roots, etc., are to be folded, the carting reduces itself to seed, artificial manure, and such produce as cereals, and the provision of the necessary access may cost little or nothing.

Drainage, either natural or artificial, is essential under British climatic conditions if the maximum returns from arable land are to be obtained. The cost of tile drainage at present prices and wages may be put at from £10 to £20 per acre, representing an annual charge of 10s. to 20s., and drainage can only be expected to be carried out if the probable increase in the annual value of the land reaches such a figure. Mole drainage, of course, provides a cheap substitute on heavy land of suitable configuration.

Water supply is of obvious importance. Apart from the amount and purity of the supply the temperature of the available water is a material point on dairy farms, since on this depends the efficient cooling of the milk.

Other forms of improvement, *e.g.* clearing of forest land, removal of stones, etc., may represent large capital sums. All the foregoing forms of capital investment must be taken into account in assessing either the freehold or the annual value of a farm. It does not follow, of course, that the value of a farm is the original value of the unimproved land plus the actual sums spent in equipment and improvement, because the actual value of an improvement may bear very little relation to its original cost. Much British land, owing

to the decline in profits from arable as compared with grass-land farming, is now over-improved and over-equipped with buildings, etc., and consequently a good part of the land-owner's outlay has been lost.

Tenant's Capital.—The movable capital of the farm, or tenant's capital, may be conveniently dealt with under the following heads:—

I. *Standing Capital*, corresponding to the "machinery and plant" of the manufacturer, and consisting of things which are used continuously or repeatedly for productive purposes, and are replaced only when they are more or less worn out.

(*a*) Work animals.
(*b*) Permanent dead stock—*e.g.* implements, machinery, harness.
(*c*) Fixed or "regular" live stock, *e.g.* dairy herds or breeding flocks maintained at a constant level.

II. *Working or Floating Capital*, corresponding to the manufacturer's "stocks in hand or in process of manufacture," and constituting that portion of the capital that is turned over, and is continually changing in form. On an arable farm in midsummer this would be represented by growing crops, unexhausted manures, etc. In winter by roots, hay, straw, unsold grain or potatoes, tillages, dung, fattening cattle, and so on. If we imagine the case of a farmer taking over a bare farm the working capital would be held, at the beginning of his occupancy, in cash. The sum required would be calculated as that necessary to meet all current expenses until such time as the farm was expected to become self supporting. The chief heads under which expenditure might be required are:—

(*a*) Seeds.
(*b*) Manures.
(*c*) Feeding stuffs.
(*d*) Temporary stocks of animals for the utilisation of surplus roots, straw, etc.
(*e*) Wages.

(*f*) Rent, rates, taxes and insurances,
and (*g*) Miscellaneous:—horse-shoeing, implement repairs, veterinary attendance, expendable stores such as coal, oil, binder twine, etc.

In practice when farms change hands the new occupier takes over from the old, at the valuation of a third party, such parts of the investment of the former as cannot conveniently be realised otherwise.

Work Animals.—In Britain the normal working unit is a team of two horses. On the heavier soils we have the exception that three may form the usual team; and on large farms the question of replacement of horses by tractors or motor-lorries, or both, must always be considered. The hire of such equipment, and also of steam tackle is a further possibility in many districts. The utilisation of electric power is a future possibility. Neglecting these last points for the moment, and allowing that an odd horse is frequently quite in place, it is important to set down some of the principles according to which the necessary staff of horses is determined. The calculation is based mainly on—

(*a*) The area of the farm.
(*b*) The kind of crops grown and the method of their disposal.
(*c*) The quantity (weight and bulk) of produce to be marketed and the distance[1] that it requires to be carted by the farmer.
(*d*) The character of the soil, from the point of view of ease or difficulty of cultivation.
(*e*) The distribution of the necessary work over the various seasons of the year.

(*a*) Other things being equal, the number of horses required is nearly, but not quite, proportional to the size of the farm. On large farms with large fields there is a certain economy of labour—*e.g.*, a 300-acre farm will require not

[1] "Distance," *i.e.*, actual mileage, is not the only factor in the labour of marketing. The quality of roads, etc., must be considered as well.

three times but somewhere about two and a half times the number of horses needed for 100 acres. Actual statistics of the horses kept on farms of different sizes, in the same area, generally show a very much larger number of acres per horse on large farms than on small, but this is in part accounted for by the increasing intensity of the system with diminishing size of farm. Thus Vaughan[1] for an area of the Cotswolds reports the following figures for four size groups:—

Size Group Acres.	No. of Farms	Average Size Acres.	Acres per Horse.	Production per Acre.	Production per Horse.
Over 500	15	599	52	£5 11 1	£289
300-500	25	352	41	6 13 5	273
100-300	28	181	33	7 9 4	246
Under 100	16	63	25	9 11 11	240

When farms are increased beyond a certain size, say 500 acres of arable, no further economy is effected because of the loss of time involved in the longer journeys to and from the fields. It is, however, in such cases that replacement of horses by mechanical power is most likely to be economical. Farms below the size that provides full employment for a pair of horses are necessarily uneconomical unless outside work can be secured.

(*b*) A rough measure of the horse-labour required for the various crops, taking that for one acre of cereal crop as a unit, is as follows:—

Per acre of cereals	1 work unit
„ fallow-crops or bare fallow	2 „ units
Per acre hay, or broadcast forage crops consumed on land	½ „ unit
Per acre broadcast forage crop soiled	1 „ „
„ pasture	⅛ „ „

The average number of such units of work that can be allotted to a pair of horses is about sixty.

If we assume that a farm horse works 210 days a year,

[1] H. J. Vaughan, *Journal of the Royal Agric. Soc.*, vol. lxxxv.

which is about an average figure, the unit is equivalent to seven horse days. This would imply that on the average an acre of cereals requires seven days' horse labour, an acre of roots fourteen, and an acre of hay three and a half. The following are the actual average figures[1] for a number of typical Oxfordshire and Gloucestershire farms in 1925:—

Wheat . . .	6·3	Mangolds . . .	18·5
Barley . . .	7·8	Sugar beet . . .	18·0
Oats	5·4	Seeds-hay . . .	2·6

An example of the unit method of calculating horse requirements may be given.

Thus on a farm of 300 acres of average loam soil, worked on a rotation of (1) oats; (2) roots and potatoes; (3) barley and wheat; (4) seeds-hay; (5) pasture, the calculation of the number of horses required might be:—

120 acres cereals	= 120	units	horse-labour
60 „ fallow-crops . . .	= 120	„	„
60 „ hay	= 30	„	„
60 „ pasture	= 8	„	„
	278		

Then 278 ÷ 60 = say, 4½ pairs or 9 horses.

(*c*) The carting away of bulky produce, such as hay, straw, potatoes, etc., involves a very considerable increase in the amount of horse-work to be performed. On the other hand, such carting frequently fills in days that would otherwise be idle, giving quite a marked increase in the number of working-days per year. The gross effect on the number of horses necessary is therefore not very great; on suburban selling farms the factor (labour units per pair of horses) might fall to 55, and on arable feeding farms, where carting is at a minimum, it might rise to 65, other conditions being average. Routine horse-work of a special kind, such as the daily delivery of milk, must be allowed for separately.

[1] Supplied by Mr Bridges and Mr Dawson of the Agricultural Economics Research Institute, Oxford.

(*d*) On the heavier soils the operations of cultivation are slower and more difficult of accomplishment and require to be more often repeated; also the number of working-days is restricted by the nature of the soil. Hence on the heavier sorts of 2-horse land the number of labour units per pair of horses will fall to about 50 or something less, while on the lighter arable soils it will rise to 70 or more. On 3-horse land 60 units per team of three may be taken as a standard figure.

(*e*) If the seasonal distribution of work is very uniform—*e.g.* where the climate is mild and moderately dry and a large variety of crops is grown, the staff of horses will be relatively small; if the winter is severe and the summer short, the operation of seeding on the one hand and harvesting on the other require to be pushed on rapidly and the distribution of work becomes irregular. Here the number of horses will necessarily be large in relation to the amount of work done during the year.

Obviously in such calculations a good deal will depend on the type of horse kept; on the way in which he is fed and cared for; and on the industry and efficiency of the man who drives him. There is the further point, dealt with later on, that on the better and more highly-rented lands the cultivation, as a whole, requires to be more intensive than on less fertile and lower-rented land, in order to secure the maximum net profit in each case. Thus, other things being equal, land worth £2 per acre might usefully carry 10 per cent. more horses than land worth £1 per acre.

The following table gives rough figures for the number of labour units per pair of horses under different sets of conditions. The total number of labour units, as arrived at by the method explained above, is taken as the measure of the size of the farm, and the annual rental per acre as a measure of the probable degree of intensiveness and the amount of direct selling of produce:—

Work Units per Pair of Horses.

	Heavy Soils.			Medium Soils.			Light Soils.		
	Rental per acre.			Rental per acre.			Rental per acre.		
	High.	Medium	Low.	High.	Medium.	Low.	High.	Medium.	Low.
Small Farms (50-150 units)	40	45	50	50	55	60	60	65	70
Medium Farms (150-300 units)	45	50	55	55	60	65	65	70	75
Large Farms (300-600 units)	50	55	60	60	65	70	70	75	80

Regarding the money value represented by farm horses, one may take £60 as a fair figure for the animal when broken and sufficiently mature for full work, and count on an average working-life of ten years. This makes the annual depreciation about £6 per horse, and brings out the average value, for all ages, at £30 each or £60 per pair.

On the broad question of the organisation of horse labour there is much to be said for the view that the system prevailing in Britain is no longer economically sound. The typical working unit, consisting of a man, a pair of strong but rather slow horses and a relatively small and usually "walking" implement has persisted unchanged since the early part of the nineteenth century, when working oxen were generally displaced. At that time relative costs of man and horse labour were very different from those of to-day. Thus Low (1843) reckons a ploughman's wage, including perquisites, at 1s. 1d. per day, while he puts the cost of maintaining a horse at £26 per annum or about 2s. 2d. per working day. At present typical figures would be 6s. 6d. per man day and 4s. per horse day. In countries like the United States and Australia, where agriculture has developed from the beginning under the burden of high wages, a very different grouping of men and horses has been adopted; typically, a man drives a team of from four to six speedy animals with a large

"riding" implement. While the output of work per horse is somewhat less under this system the output per man is vastly increased and total labour costs are materially lessened. Reorganisation on the lines indicated would of course be difficult and costly, because it would involve the replacement of many horses and most of the field implements on the ordinary farm, and the training of the staff in new methods. Clearly also the change could only be justified on the larger farms.

Farm Tractors.—The use of mechanical power in field operations, as a partial substitute for horse labour, is economical under certain conditions. Clearly steam cultivating plants and the larger types of rotary tillers can find economical employment only on farms of exceptionally large size, or where they are owned co-operatively or are maintained as a special business and are let out on hire. The smaller forms of rotary tillers have been found very useful for market garden and orchard work. But on most farms the question of mechanical power resolves itself into that of the economy of a light or medium weight tractor. Tractors were very largely used in this country during the Great War, when horses were very scarce and dear and horse maintenance costs were high. Since the close of the War the number of horses in the country has been greatly in excess of requirements and consequently they have been cheap; food costs have also been low. Hence there has been a marked tendency to abandon tractors and revert to horses. There is thus no broad basis of experience, collected under what may be called normal or stable conditions, which would enable a final judgment to be formed.

The comparative costs of maintenance of tractors and horses have been investigated by a number of agricultural economists. For example, Wyllie's figures for the south-eastern counties, covering the years 1923-1924 to 1925-1926, may be roughly averaged as follows:—

Cost of Horse Labour.

Food and Litter—	
34 cwt. concentrates (oats, maize, and bran) at 10s. per cwt.	£17 0 0
42 cwt. hay at 3s. 6d. per cwt.	7 7 0
Grazing and green food	2 5 0
Straw	1 10 0
	£28 2 0
Deduct value of manure	3 15 0
Net food cost per annum	£24 7 0
Depreciation	5 0 0
Miscellaneous—	
Man labour (excluding normal stable time)	1 0 0
Shoeing	2 15 0
Harness repairs	1 5 0
Depreciation on equipment, etc.	1 0 0
Veterinary attendance and medicines	0 10 0
Sundries	0 10 0
	£36 7 0

Average working hours per annum, 1742.
Mean cost per working hour, 5d.

Average tractor costs during the same period were approximately as follows:—

Depreciation	£28 0 0
Repairs and renewals	19 0 0
Paraffin, petrol, oil	36 0 0
Sundries	1 0 0
	£84 0 0

Average working hours per annum, 560.
Cost per working hour, 3s.

Actually average figures may have little application in particular cases, because great variations in the costs of both horse and tractor work occur between one farm and another. The figure for horse labour, for example, has been found by Wyllie to vary between 2½d. and 7d. per hour, and by Venn between 4½d. and 1s. 1d., the latter figures

including depreciation on horse drawn implements as well as the items included in the calculation above. Such variations are doubtless due in part to varying efficiency of the farmer in labour organisation, but they are caused in larger measure by conditions outwith the farmer's control—by his soil, his climate, and the system of farming which is imposed upon him by other considerations.

However, assuming that the average figures apply in a particular case, and that the wage rate is 10d. per working hour, a man with a pair of horses would cost 1s. 8d. per working hour, and a one man tractor outfit 3s. 10d. per working hour. Now a tractor of medium power will, in the case of certain operations, such as ploughing and cultivating, for which it is well adapted, perform more work than three pairs of horses. For other operations, *e.g.* cutting corn or hay, it will do fully as much as two pairs, while for still others, such as carting roots or farmyard manure, it can scarcely be used at all. The result is that on the ordinary mixed farm only a small proportion of the horses—at the most about a fifth—can be replaced by tractors, at the rate of about one tractor for each two or perhaps three horses. It will be obvious that it is only on the larger farms—say those carrying a minimum of four or five pairs—that a real saving of horseflesh can be effected. It is, however, frequently true that the land can be more efficiently worked when such replacement has been made. This happens especially where there is a limited time during which satisfactory tillage can be done, *e.g.* on heavy soils which are late in drying and have to be prepared for seeding in a very short time, or, again, where a severe winter and a short growing season on the one hand, or a dry climate on the other, render speed in working the land imperative. In such cases the maintenance throughout the year of all the horses that could be usefully employed during, say, the spring season would be economically impossible, whereas the tractor costs little or nothing for upkeep when not in use. Some farmers have been so impressed with this advantage of speed that they maintain tractors even if they

find that they cannot by so doing reduce the number of their horses.

It will be sufficiently obvious that tractors will give the best results where fields are fairly large, regular in shape, and of moderate slope. A well-drained soil is also of importance; wet spots are liable to cause great delay by "ditching" of the tractor and wet soils may suffer harm by packing.

Practically all tractors can be used as sources of power for barn machinery, *e.g.* for threshing, chaffing, bruising, etc. Where a tractor will thus replace an oil engine or other source of power in addition to performing field operations, the balance of advantage will often be turned in its favour.

Current prices of tractors range from £120 to £400 or more. So far as is known, the life, with average running time and careful management, may be from four to eight years. In the calculation given above depreciation is reckoned at 22½ per cent. The lack of mechanical knowledge among farm workers is a frequent difficulty from the point of view of upkeep, costs, and reliability. On the largest farms, where several tractors are in use, it is of course possible to employ an engineer, and it is under such circumstances that the best results have been obtained.

The motor-lorry also requires consideration as a possible part of the equipment of the farm. The heavier types are chiefly useful where they can replace both horse and rail transport, and so save double handling of goods. They can, however, only be reckoned profitable investments when the amount of transport runs into a good many thousands of ton-miles. In most districts they can be hired. The lighter type of lorries or vans may often prove a good investment when frequent deliveries of produce such as milk have to be made.

Field Implements.—Requirements in the matter of field implements are best calculated partly on the basis of the number of work horses and partly on that of the areas of special crops. For the larger ordinary mixed farm, growing cereal, fallow-crops, and hay, the following is an average

equipment per pair. The items starred are not necessary under all circumstances:—

Plough, general purpose	1	Roller, plain, medium	$\frac{1}{3}$
*Plough, chilled digging	1	Roller, Cambridge, etc., heavy	$\frac{1}{4}$
Harrows, ordinary	1	*Ridge roller	$\frac{1}{5}$
Harrows, light grass-seed	$\frac{1}{4}$	*Ridge scarifier	$\frac{1}{5}$
Harrows, chain	$\frac{1}{4}$	Turnip and mangold sower	$\frac{1}{4}$
*Harrows, chain-toothed	$\frac{1}{4}$	Corn drill	$\frac{1}{4}$
*Harrows, spring-toothed	$\frac{1}{2}$	Grass-seed sowing machine	$\frac{1}{6}$
Cultivator, spring-toothed, with horse-hoe adjustment	$\frac{1}{3}$	Artificial manure distributor	$\frac{1}{4}$
*Disc harrow	$\frac{1}{4}$	Mower	$\frac{1}{4}$
Grubber, 3-horse, heavy	$\frac{1}{4}$	Binder	$\frac{1}{2}$
Plough, double mould-board	$\frac{1}{2}$	Horse-rake	$\frac{1}{3}$
Harrow, saddle-back	$\frac{1}{4}$	Hay collector	$\frac{1}{3}$
Single row horse-hoe, 1-horse, light (drill harrows)	$\frac{1}{2}$	Carts, 1-horse / or Wagon, 2-horse	$1\frac{1}{2}$-2 / 1
Drill grubber, 2-horse, heavy	$\frac{1}{3}$	Cart, liquid manure or water	$\frac{1}{4}$

The following special crop implements also require consideration in case the acreage of the particular crop is considerable. Approximate minimum acreages that would justify the purchase of the implement in question, and approximate maximum acreage that could be worked by a single implement are mentioned in each case:—

Potatoes.—Digger (5, 40); planter (20, 80); sprayer (20, 100); sorter (10, 50).

Hay.—Tedder or swath turner[1] (30, 100); (north) hay collector or sweep (5, 20); rick bogies (in sets of two) (20, 40), and horse fork (20, 100); (south), wagon loader (20, 50), and elevator (20, 100).

The cost of such equipment, new, at current (1928) prices, would work out at from £150 to £200 per pair of horses. Allowing for depreciation at a constant rate and assuming that each implement is purchased new, and used until it is of no value, the normal investment on an established farm would be from £75 to £100 per pair of horses, or

[1] A swath turner may generally be adapted for use as a side delivery rake.

half the foregoing figures. A small addition falls to be made for the necessary hand implements—forks, hoes, scythes, etc.

It will be obvious from the list of the implements given above that small farms are necessarily at a disadvantage compared with large ones. The small man will find that he must purchase certain implements without the prospect of being able to use them to their full capacity; or that others, desirable in themselves, would not repay their cost. Vaughan gives the following figures for the average valuation of implements and machinery (including barn machinery, etc.) on farms of different size groups in the Cotswold area :—

Size Group.	Implement Valuation per acre.
	£. s. d.
Over 500 acres	1 10 5
300-500 acres	2 2 5
100-300 acres	2 7 4
Under 100 acres	3 0 2

It must be said, too, that the equipment figures given do not apply in any exact sense to different types of farms. Thus, for example, a farmer in the north with 120 acres of cereals, all ripening perhaps within a fortnight, would probably find it necessary to have three binders. A similar area in the south, where the ripening is spread over a longer period and where the climate renders harvest a less urgent business, might be satisfactorily managed with two.

The equipment for a tractor generally includes a two-furrow or three-furrow plough, a cultivator, a double disc harrow and a six- or seven-foot-cut binder. It may include, in addition, a hay-mowing attachment and spring-toothed or rigid-toothed harrow. The cost of such equipment, new, might be from £150 to £250. Naturally, the tractor implements would replace a proportion of horse implements of corresponding type.

On the question of the provision of barn machinery, it is difficult to lay down principles of general application. On the larger arable and mixed farms (with two or three hundred

acres or more under arable crops annually), it will generally be found profitable to instal a complete equipment consisting of a 20-25 h.p. oil-engine (or tractor), threshing machine (4 ft. or 4 ft. 6 in. drum), power hay chaffer, and power bruiser and grinder. The new cost of the foregoing machinery would be from £500 to £700. Other machines that may or may not be worth installing according to circumstances are: Power root pulper; power cake breaker; straw or hay baling press; straw, grain and chaff conveyers attached to threshing machine.

On small farms, apart from threshing equipment, most of these can be replaced by hand machines. Threshers of small type are fairly common in the north, while in the south the usual practice is to hire a portable thresher. The work may often be more cheaply done on the latter plan, but in the wetter districts threshing out of doors, and in large batches, is somewhat wasteful of straw; and on cattle farms, where straw is a valuable asset, a slight additional threshing cost may be justified.

Other standard equipment comprises a winnowing machine, weighing machine, ladders, sacks, stack and wagon covers, ropes, etc. Additional equipment is required for the various classes of stock; for sheep feeding a supply of netting or hurdles, troughs, corn bins, hay racks, and root cutter; for pigs, either self-feeders or food-steaming plant may be necessary; and for the dairy, churns, cooler, separator, steriliser, cheese vats, etc., according to the method of disposal of the milk. A milking machine may also be necessary. £3 per cow may be taken as an average figure for dairy equipment, but there is a good deal of variation according to the type of dairy. The installation of a milking machine in herds of 30 to 50 head may cost from £4 to £5 per cow.

Live-Stock.[1] — The live-stock carrying capacity of a farm is based mainly on the amount of home-grown food available, and the quantity of purchased feeding stuffs

[1] Permanent stocks and temporary or flying stocks are, as a matter of convenience, dealt with together.

that it will ordinarily be advisable to use in conjunction. Other considerations that may arise are the amount of housing and sometimes the quantity of litter available.

The requirements of the work horses form a first charge on the supplies of food, litter, and housing. The annual requirements of a farm horse of good size (1500 lb.) on an ordinary mixed farm might be calculated, in terms of starch equivalents, somewhat as follows:—

Maintenance, 365 days at 5½ lb. starch equivalent per day . . .	= 2000 lb. starch equivalent.
Work, say 200 working-days of nine hours = 1800 hours at 1½ lb. starch equivalent per hour . . .	= 2700 lb. „
Total . . .	= 4700 lb. „

These requirements might be met by:—

2 tons oats at 60 lb. starch equivalent = 120 units × 22·4	= 2700 lb. starch equivalent.
1½ tons hay at 30 lb. starch equivalent = 45 units × 22·4	= 1000 lb. „
½ ton oat straw at 18 lb. starch equivalent = 9 units × 22·4 . .	= 200 lb. „
⅔ acre pasture, or say 4 tons grass at 10 lb. starch equivalent = 40 units × 22·4	= 900 lb. „
Total . . .	= 4800 lb. „

The litter requirement is less definite, but may be put at between 30 cwt. and 2 tons of wheat-straw or its equivalent annually. Hence, on the ordinary sort of mixed farm, the requirements of a work horse might be met by 2 acres of oats (grain), 1 acre hay, ⅓ acre oat-straw, 1 acre wheat-straw, and ⅔ acre pasture.[1]

[1] The proportions of the various foods are different from those given on p. 574, but the total food value is very nearly the same. Wyllie concludes from his figures: "It appears that the average horse consumed the produce of about 2 acres of corn (chiefly oats), about 1¼ acres of fodder and hay, and about 1 acre of grass in addition to bran, green-meat, and straw."

Apart from work horses, the live-stock of the farm may be regarded from many different points of view. At the one extreme we have farms whose whole produce is marketed in the form of live-stock products—either animals themselves or, *e.g.*, milk or wool. Here the object will generally be to maintain as much stock as the farm can conveniently carry. At the other extreme we find farmers whose main income is derived from the sale of crop products such as grain and potatoes. Here the function of the live-stock is to convert the by-products of the farm into marketable form, and to assist, by their manure, in the maintenance of the fertility of the land. In such cases the live stock will be reduced to the minimum consistent with the objects in view. This point is further dealt with in the succeeding chapter, but obviously the question of whether the live-stock constitutes a primary or only a secondary department of the farm will affect our calculations of stock-carrying capacity.

Summer Stock—Pasture.—A convenient method of calculating stock for pasture is to reduce the various classes of grazing stock to a common basis. A convenient unit is the food requirement of a dairy cow of average size ($10\frac{1}{2}$ cwt.), yielding 2 gallons of milk daily. Such an animal will do quite well on pasture of ordinary quality without any additional feeding, and may be reckoned to require a ration of 12 lb. starch equivalent per day. In the following table the daily food requirements of various classes of stock are set down; an assumption is made regarding the amount of starch equivalent fed in the form of concentrates, the difference giving the amount of starch equivalent that would necessarily be derived from grass. In the last column is given a number or fraction representing the pasture units to be allotted to each animal of the various types.

	Live-Weight Cwt.	Total Daily Ration (Starch Equivalent).	Concentrate Ration (Starch Equivalent).	Grass Ration (Starch Equivalent).	Pasture Units per Head.
Cattle.					
Milch cows yielding 2 gall. per day	10½	12	...	12	1
Fattening bullocks	10½	13½	1½	12	1
Dairy and store stock—					
6 to 12 months	4	6	...	6	½
12 to 18 months	6	7½	...	7½	⅝
18 to 24 months	8	9	...	9	¾
Cattle for early fattening—					
6 to 12 months	5	7½	...	7½	⅝
12 to 18 months	7	8½	...	8½	⅞
18 to 24 months	9	10	...	10	⅚
Sheep.					
Breeding ewes, large, with twin fattening lambs	lbs. 200	5	1	4	⅓
Do. with single fattening lambs	...	3¾	¾	3	¼
Do. with twin store lambs	...	4½	½	4	⅓
Do. with single store lambs	...	3¼	¼	3	¼
Breeding ewes, small, twin lambs	120	3¾	¾	3	¼
Do. with single lambs	...	3	½	2½	⅙
Yearling sheep—					
Fattening	100	1⅔	⅔	1⅙	1/10
Store	100	1⅙	...	1⅙	1/10
Fattening weaned lambs	80	1½	3/10	1⅙	1/10
Horses.					
Draft mare (and foal)	1500	15	...	15	1¼
Yearlings	700	8	...	8	⅔
Two-year olds	1000	10	...	10	⅘

The value of pasture of course varies within wide limits, both as to the weight of grass produced and its feeding value. First-class British pastures, however, leaving out a limited number of exceptionally rich ones, may produce about 8 tons of green grass during the season, with a starch equivalent of about 12, say nearly 1 ton of starch equivalent, which is just equal to 12 lb. per day for a six-months'

grazing season. An acre of such pasture is therefore equivalent to one unit in the foregoing table. Other types of pasture will carry stock in something like the following proportions:—

Finest permanent fattening pastures and first year seeds pastures on best arable land	= 1¼ units per acre.
First-class permanent pastures and first year seeds pastures on average arable land	= 1 unit ,,
Good permanent pastures and pastures of second and subsequent years on average arable land	= ¾ ,, ,,
Poorer lowland and average semi-upland pastures	= ½ ,, ,,
Hill pastures	= ⅓ to ⅕ unit ,,
Mountain grazings	= 1/20 to ⅕ ,, ,,

The carrying capacity of a pasture depends on the proportions of the various classes of stock placed upon it. It is least when the stock is exclusively sheep or horses, and is probably greatest when the stock comprises a large proportion each of sheep and store cattle with a few horses. Stocking must further depend on the amount of winter grazing that is wanted; if a considerable amount of rough grass is to be left as wintering, the pasture must not be fully stocked for the summer season.

The following calculation shows the application of the foregoing data.

A mixed farm of fair fertility provides 20 acres first year seeds pasture, 40 acres second year seeds pasture, and 80 acres secondary permanent pasture. The number of units would accordingly be—

20 acres first year seeds	= 20 units.
120 acres second year and permanent pasture	= 90 ,,
Total	= 110 ,,

The stock carried might be—

6 work horses at $\frac{2}{3}$ unit	=	4·0 units.
2 brood mares and foals, at $1\frac{1}{4}$ units	=	2·5 ,,
2 yearlings, at $\frac{2}{3}$ unit	=	1·3 ,,
2 two-year olds, at $\frac{4}{5}$ unit	=	1·6 ,,
30 dairy cows	=	30·0 ,,
4 heifers, six to twelve months, at $\frac{1}{2}$ unit	=	2·0 ,,
4 heifers, twelve to eighteen months, at $\frac{3}{5}$ unit	=	2·4 ,,
4 heifers, eighteen to twenty-four months, at $\frac{3}{4}$ unit	=	3·0 ,,
200 large breeding ewes—		
100 with single lambs, at $\frac{1}{4}$ unit	=	25·0 ,,
100 with twin lambs at $\frac{1}{3}$ unit	=	33·0 ,,
50 yearling ewes, at $\frac{1}{10}$ unit	=	5·0 ,,
Total	=	109·8 ,,

It will generally be wise to adjust the permanent stock of the farm at, say, 10 per cent. below the theoretical carrying capacity, otherwise in seasons of drought the farmer will be faced with the alternative of selling stock in a bad market or of purchasing large quantities of expensive concentrates.

Under the intensive system of pasture management, with rotational grazing and heavy nitrogenous as well as other manuring, the carrying capacity of the middle grades of pasture can be increased to between two and two and a half times their normal level. It is doubtful whether the same relative increase can be secured on first class pastures; on the poorer classes—*e.g.* mountain grazings—the intensive system could clearly not be economically successful.

The stock-carrying capacity of soiling and forage may be calculated in much the same manner. Yields of forage may vary from 6 to 15 tons or more in the case of crops that occupy the ground for a full growing season; 8 to 10 tons is an ordinary yield of the usual mixtures grown for soiling, *e.g.* mixture of oats, beans, peas, and vetches; rye-grass and clover mixtures when cut twice will give comparable yields. Catch crops naturally yield less, depending on the length of time that they occupy the ground. The starch equivalent of green stuff varies from 8 to 12 or 13 per 100 lb. Under suitable conditions for arable forage

crops the carrying capacity per acre may be increased by 50 per cent. or more by substituting soiling and forage crops for pasture. This, however, is frequently insufficient to meet the extra charges involved.

Winter Stock.—For winter stocking, general rules cannot be laid down, because the requirements of different classes of animals are not even roughly comparable. The following facts may, however, be usefully stated.

Litter.—After deduction of the quantity necessary for thatch, covering clamps, littering horses, etc., the wheat and a good deal of the barley straw produced will normally be used as litter for housed cattle or pigs. The allotment may vary within wide limits. Where straw is scarce, and regarded as a commodity of considerable value—*e.g.* on semi-arable dairy farms, or north-country cattle-feeding farms—7 lb. per head per day, for full-sized cattle in stalls, is regarded as ample. In such cases, however, there is considerable wastage of liquid and of nitrogen. For cattle in covered courts, a daily allowance of 14 to 16 lb. per head (varying somewhat according to the quantity of roots fed) will ensure the animals a comfortable bed and the production of the best quality of farmyard manure, but is insufficient completely to prevent loss of nitrogen. Where the cattle are running in partially open yards, and where the object is rather to tread down a maximum quantity of straw into manure, 20 to 30 lb. per head may be allowed and dung of still fair quality be produced. The allowance for young stock kept indoors may be reckoned at between 1 and 2 lb. per 100 lb. live-weight per day. The allowance for pigs may be taken on the same basis.

Fodder Straws.—The utilisation of cereal straw as fodder can be attained practically only with cattle. A limited amount may be fed to sheep, chaffed and mixed with grain, and horses may consume quantities in periods when work is light. Oat straw, in cattle-feeding and dairying districts, is generally all fed if there is sufficient other material to serve as litter. Barley straw is used as fodder in districts where oats are not satisfactory. For cattle on full production rations the maximum daily ration of straw will be about

12 to 14 lb. per 1000 lb. live-weight. A larger proportion makes the ration too bulky in proportion to its energy value. Cattle being kept at little over a maintenance level—*e.g.* dry cows—may consume up to 20 lb. per 1000 lb. live-weight per day. Straw is of course unnecessary if other roughage, such as hay, is available and can be used economically. Where there is a possibility of selling straw this method of disposal should be considered; the market is, however, a very limited one. If farmyard manure can be bought in exchange, the whole of the straw may be so disposed of, but where this is not possible the proportion to be sold must be decided according to the nature of the soil of the farm, especially with regard to its humus content. Thus black fen soils do not require farmyard manure, and the whole of the straw may be sold. At the other extreme, light soils, in the drier districts, decline in fertility so rapidly when farmyard manure is withheld, that the selling of straw is generally to be avoided altogether.

Hay, since it is a primary product and not a by-product, must be regarded quite differently from straw; that is to say, no more need be produced than can be profitably used. For many purposes straw can be used as a substitute for hay, and hence on grain farms the growing of hay for home consumption is reduced to a minimum. Hay is, however, from 50 to 100 per cent. higher in energy value, weight for weight, than straw and its content of protein is from three to ten times as high.

Hay may be regarded as indispensable for horses on regular work, the annual allowance per horse varying from 25 to 50 cwt., according to the type of horse used and the distribution and amount of the work to be done. For young horses in winter a certain amount is generally necessary, 5 to 10 cwt. per head representing their requirement where the animals have a good range of winter pasture.

For cattle up to one-year old, hay will generally form part of the winter ration, and the minimum allowance may be put at about 1 per cent. of the live-weight per day. Sheep fattening or wintering on roots should have hay at the rate

of not less than one-half per cent. of the live-weight daily; to grass wintering sheep and cattle, hay may be supplied regularly or only during spells of severe weather.

At the other extreme, *e.g.* on grassland dairy farms, hay forms the basis of the winter ration, and may be fed to cattle at the rate of fully 2 per cent. of the live-weight daily.

Roots, having a high energy value in relation to their dry-matter content, and being succulent and very palatable, form the most satisfactory complement to straw in the feeding of all classes of cattle. Hence where the available fodder consists mainly of straw, roots will generally have to be given in considerable quantities if a full production ration is required. The maximum root ration for growing and fattening cattle may be reckoned at 8 per cent. of the live-weight daily. At this rate an average bullock would consume 7 to 8 tons, or somewhat under half an acre of an average crop, in a six months' feeding period. For dairy cows about three-fourths of this quantity should be regarded as the normal limit, the energy requirement of the ration being made up in other ways. Owing to the large labour requirement of the root crop and the rise in wages in relation to agricultural prices the tendency is for root rations to be reduced far below these figures. The economic ration in particular cases will of course depend on the ease or difficulty of growing the crop. Where hay is fed in place of straw the root ration may be reduced to any extent that may be desired, or eliminated entirely.

Sheep may receive relatively more roots than cattle—up to 15 per cent. of their live-weight daily for full production, and even in maintenance and low production rations, roots usually take a more prominent place. It is to be noted that the cost of the crop to sheep is less than to cattle, since normally sheep consume a considerable proportion of their roots in folds, and the costly business of lifting and carting is avoided.

Fattening and breeding hoggets of the larger lowland breeds may be given 1 cwt. per week, allowing for a certain

amount of wastage, or 1 ton in a winter feeding period of five months. Breeding ewes of the larger lowland types will require about the same quantity, but much depends on the date of lambing and on the amount of pasturage and other food available.

Work horses may receive up to 20 lb. of roots per day, and young horses, in proportion to their live-weight, rather more. Pigs may be fed on roots in considerable quantities—up to 7 or 8 per cent. of their live-weight daily, provided that the other feeding stuffs are judiciously chosen.

Silage is best regarded as a substitute for part of the roots and hay, or for part of the roots, straw, and concentrate of a ration. It cannot be regarded as a simple substitute for roots, because it provides much less net energy value (about two-thirds) in a given quantity of dry matter. Actually 30 lb. of average silage will replace about 50 lb. roots and 3 lb. straw.

The amount of by-products, such as small potatoes, tail corn, etc., affect the carrying capacity of the farm to a minor extent. Considerable quantities of home-grown oats, barley, and beans are sometimes fed to stock, but these are ordinarily to be regarded as alternatives to purchased concentrates and thus hardly enter into stocking calculations.

The following is an example of winter stocking:—

Production of feeding stuffs and litter—

Wheat straw, 30 acres, at 35 cwt. per acre	=	52 tons
Barley „ 10 „ 20 „ „	=	10 „
Total litter straw	=	62
Oat straw, 40 acres, at 25 cwt. per acre	=	50 „
Seeds hay, 20 „ 35 „ „	=	35 „
Meadow hay, 10 „ 30 „ „	=	15 „
Total hay	=	50 „
Roots, cabbages, kale, 30 acres, at 20 tons per acre		
Less, say, 10 per cent. wastage	=	540 „

Consumption.

	Mean Daily Ration per Head. Lb.				Duration of Period.	Total Consumption. Tons.			
	Litter.	Oat Straw.	Hay.	Roots.	Days.	Litter.	Oat Straw.	Hay.	Roots.
Thatch, etc. .	...	...	...	...	...	4	...	...	...
6 work horses .	14	4	14	10	280	10·5	3	10·5	7
4 young horses .	7	...	7	10	150	1·9	...	1·9	3
40 dairy cows .	7	8	7	40	200	25·0	28·6	25·0	143
8 heifers, 0 to 12 months . .	5	...	6	30	180	3·2	...	3·9	19
8 heifers, 12 to 24 months . .	7	10	4	40	180	4·5	6·4	2·6	26
200 breeding ewes . .	...	...	¼	16	100	...	...	3·3	143
50 ewe tegs .	...	...	½	14	120	...	...	2·0	37
50 fattening tegs	...	...	½	16	120	...	...	1·3	43
15 fattening cattle . .	12	12	...	100	150	12·0	12·0	...	100
			Total .	.	.	61·1	50·0	50·5	521

The Working or **Floating Capital** comprises that part which is regularly "turned over," that is to say, realised and reinvested. The rate of turnover varies with the nature of the product. In a fresh milk dairy, capital is invested in food and labour, and a return obtained from sales of milk practically concurrently, with the result that the amount of working capital required is negligible. In producing a spring cereal, the capital represented by seed, manure, and tillage will be laid out for a period of from six months to a year; that spent in threshing may be realised again almost at once. If grass seed be sown with the cereal crop, the capital so invested will be realised only after one or more years; and if the grass be manured with slag the return may be expected to be spread over a period of four or five years.

In practice the amount of floating capital required may be arrived at in either of two ways. Firstly, taking a farm at any season of the year, the working capital actually invested at the moment may be added to the prospective

outlays that will require to be made up till such time as receipts may be expected to begin to equal or exceed expenditure. Thus, if we enter an arable selling farm at Candlemas (2nd February), the outgoing tenant having disposed of the whole of the previous season's crop, we should pay for tillages that had been carried out, for hay seed and wheat seed already sown, and for manures and unexhausted residues. We should then proceed to estimate our probable outlays, under the heads of seeds, manures, wages, feeding stuffs, rent, insurance, and sundry maintenance charges up till, say, September or October, when sales on a considerable scale would commence, and our investment would cease to grow.

Alternatively, the total investment of floating capital may be estimated directly for the particular season of the year when it will be at its maximum. Thus, in the foregoing case, we should estimate the probable investment represented in the crop, manurial residues, etc., just after the completion of harvest, and the sum so obtained would represent the maximum working capital required.

It will be obvious that, where the requirements of working capital vary considerably from one season to another, the farmer may find it in his interest to obtain credit for part of the year rather than to have a large amount of capital lying idle at other seasons. Thus in Fig. 62 the investment in the main items of floating capital on a large arable farm is shown. The farm grows 200 acres grain, 60 acres potatoes, 60 acres roots, and 60 acres hay. The live stock consists entirely of cattle and sheep which are bought in autumn to consume the roots and straw and are sold fat between February and May. The actual working capital is £5000. In April and May, after the winter stock has been sold, the farmer has a cash balance of £1500. In November, because the winter stock has to be purchased before any considerable amount of the grain and potatoes has been realised, he has an overdraft of about the same amount. The exact amount of working capital that it would be profitable to employ, *e.g.* whether £3000, £4000, or £6000, would depend on the relationship between farming profits and bank interest.

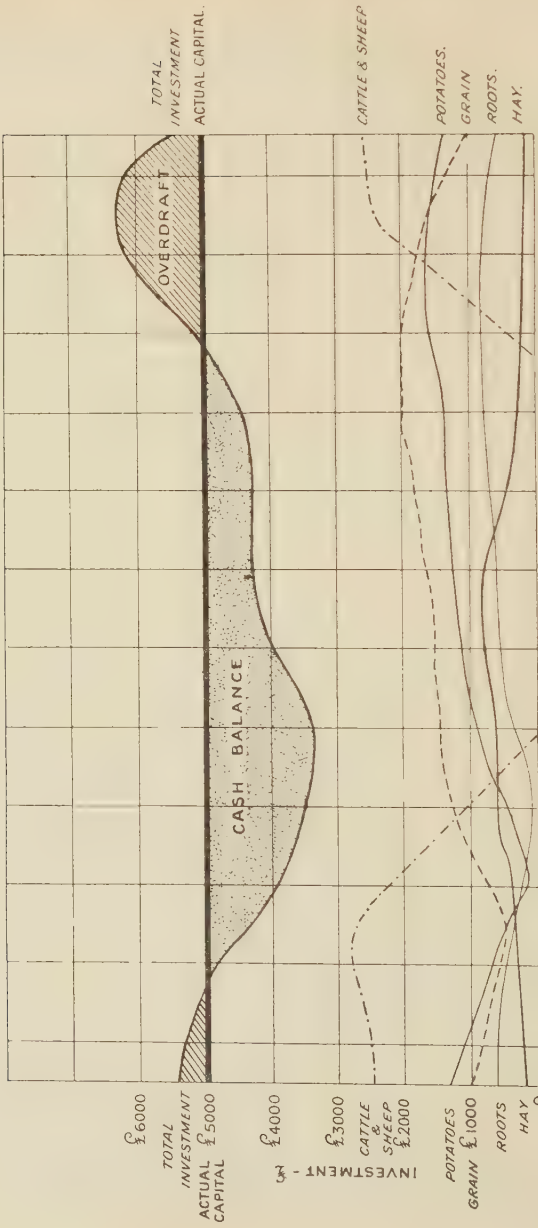


FIG. 62.—Seasonal changes in the floating capital of an arable farm.

Obviously, if a farmer could make 8 per cent. on his working capital and the rate of overdraft interest were 5 per cent., it would pay him to borrow as heavily as he could.

Farm Labour.

Labour requirements may be arrived at approximately on the basis of the acreage of the several crops cultivated and the numbers of the various classes of stock maintained.

With regard to the common crops, the following figures are based on data collected by various agricultural economists.

Man Labour—Days per acre.

	Maximum.	Minimum.	Average.
Cereals and beans	9	4	7
Peas	12	7	10
Potatoes	40	20	33
Roots—carted	25	15	20
„ folded	14	10	12
Sugar beet	40	20	28
Carrots	70	50	60
Rape, vetches, etc., folded	8	4	6
Hay	3	2	2·5
Pasture	1	0·1	0·3
Pasture, intensive system	3	2	2·5

The wide variations in the figures have to do with the ease or difficulty of cultivation, the degree of intensity of the system, the distances from the homestead, the efficiency of the labour and a variety of minor factors.

The following are the corresponding figures for the more important classes of stock :—

Man labour—Days per head per annum.

	Maximum.	Minimum.	Average.
Dairy cows (hand milked)	30	20	24
Other cattle, housed	10	6	8
„ outside	5	3	4·0
Pigs—indoor system	2	1·2	1·5
„ outdoor system	3	2	2·5
Sheep—arable	2	1	1·5
„ semi-arable	1·4	0·7	1 0
„ grassland and mountain	1	0·5	0·7
Poultry	0·6	0·3	0·4

Here much depends on such factors as the arrangement of the farm buildings, on the water supply to the fields, and obviously on the value of the individual animals.

Taking average figures throughout, and neglecting for the moment the question of the seasonal distribution of the labour, the following is a calculation of the labour requirements of a mixed farm of 432 acres:—

			Man Days.
Cereals	100 acres	× 7	= 700
Roots carted	30 „	× 20	= 600
Roots folded	8 „	× 12	= 96
Potatoes	8 „	× 33	= 264
Sugar beet	6 „	× 28	= 168
Hay	80 „	× 2·5	= 200
Pasture	200 „	× 0·3	= 60
Dairy cows	40 head	× 24	= 960
Other cattle	80 „	× 6[1]	= 480
Sheep—semi-arable	250	× 1	= 250
Poultry	800 head		= 320
		Total	4098

Taking the number of working days per man per annum at 290, the average number of persons employed would be $\frac{4098}{290}$ or nearly eighteen. Actually a certain amount of labour would be casually employed, and the regular staff might be either sixteen or seventeen.

Supervision.—The amount of supervision that is necessary varies greatly with the type of farm and the efficiency of the labour. Under average conditions an allowance of about 5 per cent. of the time of a supervisor may be made for each worker employed. This would imply that on a farm employing 20 persons, a bailiff or steward would have full employment in supervision, whereas on one employing 10 persons he could be engaged for half his time in manual work.

The labour requirement is of course by no means absolutely or permanently fixed. The question for consideration is rather that of the amount that can be *profitably* employed. This involves the whole question of the relation

[1] Assuming that the cattle are housed for half the year.

between wages and the prices of agricultural products, which is dealt with later in this section. It also involves the question of labour-saving machinery. Before a machine can be profitably introduced it must be shown that it will enable work to be done more cheaply (having regard to the quality of the work) than it can be done by hand. That is, the total of the charges for interest, upkeep and depreciation, fuel or other materials, must be less than the sum that would be required for wages if the work were to be done by hand.

The relative rates at which the work can be done by hand and by machine is a further point that must be considered unless casual labour is easy to secure. Since a judgment on these points can only be arrived at on the data of each particular case, it will be seen that labour requirement must vary from time to time, and from place to place, according to the relative cost of labour and of machinery. Thus in the United States, where wages are higher than in Britain, more machinery can be profitably used, and the number of labourers is low. In Poland, before the war, it was reckoned to be barely profitable to use binders in harvesting, because the work could be done about equally cheaply by hand. In this country conditions are steadily tending towards a reduction in the number of farm workers and an increase in the use of machinery.

Periods of engagement, conditions of service, wages, and the manner of payment vary considerably in Britain. In Scotland contracts are generally made for periods of six or twelve months. In England the period is nominally a week, but in practice all stockmen and carters, and a proportion of other workers, are regularly and continuously employed.

In England and Wales hours of work, minimum wages, overtime rates, etc., are fixed under the Agricultural Wages (Regulation) Act, 1924, by County Agricultural Wages Committees, whose decisions have the force of law. At present (1928) the standard minimum wage for ordinary labourers of twenty-one years or over varies from 30s.

per week in some of the southern counties to 35s. and occasionally more in industrial areas in the north. The hours of work vary from county to county, but forty-eight hours weekly in winter and fifty-two in summer is a common arrangement. Carters and stockmen may receive the same standard wage, with overtime rates for the additional hours worked, or may have higher rates to cover longer hours. In either case earnings are usually from 3s. to 10s. per week more than those of other labourers. There is always a scale for workers of less than twenty-one years old. In practice the minimum wages fixed by the committees are the actual wages paid to a majority of the workers; only bailiffs, stockmen in pedigree herds, cowmen in dairies producing graded milk, etc., are paid at higher rates.

In Scotland wages are arranged by bargaining, either between the employers' and workers' unions, or between the individuals concerned. In some areas there are more or less standard wage rates for the various classes of labour, while in others the wage is a matter for individual negotiation. The average wage for married ploughmen was about 40s in 1928, and that for single ploughmen about 33s., the latter including a considerable proportion of young workers.

It is the practice in many districts to pay a part of the wages in kind. In England fixed values are attached by the Wages Boards to all perquisites such as free cottages milk, potatoes, etc. In the south such perquisites are small in amount, but in certain areas of the north and of Scotland, as much as a fourth of the total wage may be paid in the form of allowances. Even there the tendency is to increase the proportion paid in cash.

Piece-work rates, or other methods of payment by results, can be applied in certain cases to farm work. Casual labour used in operations that allow of easy measurement of the work done and easy inspection of its quality may be paid on a simple piece-work system. Among the operations often let out at piece rates are those of cutting drains, laying and trimming hedges, spreading manure, dibbling cabbages, singling roots, hand-hoeing, raising roots, and thatching.

Various forms of bonus payments are occasionally made, particularly to stockmen.

Profit-sharing schemes, according to which the labourer has a certain fixed wage, and in addition a share of the net profits of the farm, are in operation here and there, and are giving generally satisfactory results.

CHAPTER II

THE CHOICE OF THE DEPARTMENTS OF THE FARM

THE first problem that arises in the organisation of the farm is the choice of departments—the choice of the particular commodities that the farm is to be made to produce. Selection from among the various possibilities should never be an arbitrary matter, but should be based on a thorough understanding of all the conditions, natural and economic, under which the farm will have to be carried on.

The chief marketable products of British agriculture are cereal and other grains; potatoes and other vegetables; sugar beet; beef, mutton, and pork; wool; milk, butter, and cheese; horses; and poultry and eggs. In certain cases (as, for example, that of beef), the process of production is often divided into two or three stages, so that in fact there are more departments in the industry than there are marketable products.

Grain.—While it is of course true that the various cereal crops have different individual requirements in regard to temperature, moisture, manure, etc., yet it is possible to lay down certain principles regarding corn growing generally. It is to be understood that the production of grain for sale is the question immediately under discussion. The use of cereals for the production of stock food is dealt with later.

The conditions affecting the economic success of cereal cultivation are briefly as follows:—

(1) *Climate.*—The operation of seeding, and more particularly that of harvesting, are most cheaply and most efficiently performed under dry conditions. Under the best conditions, such as prevail, for example, in the great wheat belt of North America, cereals may be cut, left on the ground for a few days, carted, threshed and despatched

to the elevator with a minimum of labour and small risk of damage. In our own wetter areas there is loss and additional expense at every stage. The moisture requirement of cereal crops is on the whole low, and full yields may be obtained with a rainfall of from 20 to 25 in. per annum if other conditions are suitable. A rather high amount of sunshine is beneficial both in respect of yield and quality. Thus cereals are most profitably cultivated in the drier and sunnier districts, that is to say, in the east of Britain rather than in the west.

(2) *Soil.*—Compared with other annual crops, cereals are easily satisfied as regards tilth. This arises partly from the fact that they are relatively frost hardy, and can be sown either in autumn or early in spring when moisture is plentiful in the soil; and partly from the fact that the seeds are large, can be sown at a fair depth, and germinate readily. Cereals are therefore relatively safe crops on the more extreme types of arable soil. This fact is exemplified in the high proportion of the arable area devoted to cereals on the heavy clays of Essex and the thin dry soils of the Chalk.

(3) *Markets.*—Cereal grain has a fairly high value in relation to its weight, is non-perishable, and with modern facilities is easily and cheaply handled and transported. Hence proximity to market means relatively little in the value of the produce—on land that is near to markets the tendency will rather be to concentrate on the bulkier or more perishable commodities, so that grain growing is left to the more remote areas. This tendency may be negatived if there is a market demand for straw as well as for grain, because straw is very costly to transport in relation to its value. The market demand for straw is, however, a very limited one.

(4) *The Size of the Holding.*—A considerable amount of machinery—drills, binders, threshing and dressing machines—can be profitably employed in the production of corn where it is grown on a considerable scale, and transport and marketing can be arranged on better terms where large quantities are dealt in. There is little or no compensating advantage in small scale production. Hence,

other things being equal, the cereals occupy a more important place on large farms than on small.

(5) *The Labour Requirement* of cereals, compared with that of other arable crops, can be brought down to a rather low figure. Hence high wages do not in themselves mean that cereals cannot be profitably grown. Of more consequence from the point of view of organisation is the question of seasonal distribution of labour. On the whole this is very uneven; at the worst one may have a labour distribution such as the following, which refers to a crop of spring barley:—

	Man—Days. per acre.	Horse—Days. per acre.
April—Ploughing and seeding . . .	2·2	4
August—Cutting and carting . . .	2·4	1
Sept. to March—Threshing and marketing	1·6	0·6
	6·2	5·6

Since seed-time and harvest are the periods of pressure, it will be clear that the extent of cereals that can be grown will depend partly on the supply of casual labour for these periods and partly on the length of the periods over which planting and harvesting can be spread. The sowing of both winter and spring varieties will ease the pressure of work at seed-time and, in districts where winter oats and winter barley succeed, the harvest can likewise be spread over a longer period, because these crops mature before wheat or spring corn. In the north, and at the high elevations, where there is often barely time for the crops to be sown, ripened, and harvested within the limits of the season, the growing of corn for market ceases to be an important object.

(6) *Capital Requirements* for cereal cultivation are comparatively low. Costs of production under typical British conditions amount to something of the order of £10 per acre.

(7) The necessity for *Weed Control* sets a limit to the frequency of recurrence of cereal crops on the same land, a point that is well recognised by farmers everywhere. It is

true that certain weeds, such as charlock, spurrey, and corn buttercup, can be combated by spraying, and a certain amount of control can be obtained by harrowing in the early stages and by horse- and hand-hoeing. But weeds are much more cheaply and effectively dealt with when the ground is not occcupied by a cereal crop. It is possible, especially in the south and where steam tackle or tractors are available, to carry out a considerable amount of fallow cultivation (autumn cleaning) after the grain crop has been removed from the land; but in the main, as far as weed control is concerned, reliance must be placed on other crops, or failing such, on bare fallows.

(8) The possibilities in regard to *the utilisation of straw*, where this cannot be sold, have a rather important bearing on the profits of grain growing. Up to a certain point, in relation to the production of roots especially, straw has a very considerable value, notably where other conditions tend to favour the cattle industry (dairying, rearing, or feeding). The larger the place occupied by cereals in the system, the less does the value of the straw become, until in the extreme case (*e.g.* on the American Prairie wheat farm) it is regarded as worthless and is burnt. It has been shown, of course, that straw may be converted into "artificial dung," and generally it will have some value for this purpose. But such is very low compared to its value in districts like Aberdeenshire, Ayrshire, or Cheshire, where large numbers of cattle are maintained and where the winter house-feeding period is long. Broadly speaking, the value of straw is inversely proportional to the quantity that is produced, and this fact tends to reduce the amount of variation in the cereal area in different districts.

The special requirements and preferences of wheat, barley, oats, and rye in the matter of soil and climate, and also the relative yields of grain and straw, are mentioned in Book II.

The statistics as shown in table on next page illustrate the effect of soil and climatic conditions in determining the proportions of the several species of cereals.[1]

[1] 1926 figures.

County.	Mean Annual Rainfall. Inches.	Mean July Temperature.	Mean Bright Sunshine. Hours per day (July).	Predominant Soil. Type.	Percentage of Cereal Area under			
					Wheat.	Barley.	Oats.	Rye.
Essex . .	23	62	7·0	Heavy	45	31	24	...
Norfolk . .	24	61	7·0	Light	27	53	18	2
East Lothian .	26	58	5·5	Medium	14	39	47	...
Elgin . .	26	57	4·7	,,	2	23	75	...
Worcester .	30	62	6·2	Heavy	53	6	40	1
Shropshire .	30	61	6·0	Medium	29	22	49	...
Aberdeen .	30	56	5·0	,,	...	7	93	...
Cheshire . .	32	60	6·0	Heavy	17	2	79	2
Stirling . .	35	58	4·7	,,	9	3	88	...
Devon . .	42	61	6·6	Medium	21	13	66	...
Dumfries . .	42	58	5·7	,,	...	...	100	...

Beans and Peas grown as seed crops are relatively unimportant in Britain, occupying an area equal to about 5 per cent. of the cereal area. The inclusion of leguminous grains in the farming scheme is of course advantageous from the point of view of maintenance of fertility and economy of nitrogenous manure, on which the cereals make a high demand.

Peas are more costly to harvest and more susceptible to damage by wet weather than are cereals, and the factors chiefly affecting their distribution are the amount of sunshine and of summer rainfall. Their cultivation is thus mainly confined to the eastern and south-eastern counties of England from the East Riding of Yorkshire to Surrey and Sussex; Worcester being the only notable exception. The proportion of the crop is the largest (from 5 to 10 per cent. of the cereal area) in Kent, Essex, Suffolk, and Lincolnshire. Pease straw (from the ripe crop) is comparable in energy value to the better cereal straws, and has a protein content equal to that of average meadow-hay. It is commonly used for sheep feeding. The dried haulm from picking peas has a higher feeding value, almost equal to that of hay. The pea crop is expensive to grow and rather speculative, but the returns in good years are high.

Beans have somewhat the same preferences in regard to

climatic conditions as peas, *i.e.*, they do better in the drier and sunnier districts of the east than in the wetter and duller western districts. On the other hand, the crop is much less dependent on good harvest weather, being in fact considerably less susceptible to damage by rain than the cereals. The result is that the northern limit of cultivation is higher than that of peas, as evidenced by the considerable areas grown in Scotland as far north as Perthshire. On the other hand, the distribution is more strictly governed by soil conditions, there being a close correlation between the clay area and the bean area in various districts. Beans can be summer tilled more economically than cereals, though they do not form a really satisfactory fallow crop. Bean straw has a high feeding value, especially in northern districts where the crop is liable to be somewhat under-ripened. The feature of unreliability in yield (caused in this case largely by the incidence of aphis attacks) is shared with the pea-crop; the amount of variation from year to year in the average British yield is about half as large again as in the case of wheat.

Potatoes.—Next to the cereals, potatoes form by much the most important of our market crops.

(1) *Climate.*—Potatoes thrive under a wide range of climatic conditions, and, broadly speaking, their distribution is governed to a very minor extent by the incidence of sunshine, rainfall, and temperature. This is exemplified by the acreage returns for the various counties. Among those with the highest proportion of their arable area under potatoes are the Holland Division of Lincoln, the Isle of Ely, Lancashire, Fife, Dumbarton, and Shetland, while among those where the potato area is almost negligible are Wiltshire, Berkshire, Suffolk, Roxburgh, and Aberdeen. The incidence of late and early frosts is, however, an important consideration, and freedom from the former is generally the governing factor in locating early potato areas. Another rather important point is that a cool and not too dry climate gives healthy and vigorous stocks, whereas in hot and dry regions stocks become affected with mosaic, leaf-roll, etc., and "run

out." The demand for Scottish seed from English growers tends to the extension of the area of the crop in the north. Under warm, moist conditions the risk of blight tends to make production more costly.

(2) *Soil Conditions* have a very large influence on production costs. The best soils are deep, free-working loams; the worst are heavy clays and thin, dry, calcareous soils. The heaviest yields are obtained from rich black fen land, the finest quality from red loams. The crop withstands a considerable degree of soil acidity and may suffer if the lime content of the soil is high.

(3) *Markets and Transport Facilities.*—The weight of marketable produce per acre is about six times as high from potatoes as from grain. Hence transport charges figure largely in the final costs, and proximity to markets, railway stations, seaports, canals, etc., has an important bearing on the position that potatoes occupy in the farming scheme. For example, two farms, similar in all other respects, are so situated that the costs of transporting goods to a common market are respectively 10s. and 20s. per ton. The rents are respectively £3 and £2 per acre, and the yields obtained in each case are 20 cwt. of wheat and 6 tons of potatoes. The following figures show the relative results from wheat and potatoes respectively in each case:—

	Farm A.						Farm B.					
	Wheat.			Potatoes.			Wheat.			Potatoes.		
	£	s.	d.	£	s.	d.	£	s.	d	£	s.	d.
Rent per acre	3	0	0	3	0	0	2	0	0	2	0	0
Labour and other costs per acre	7	0	0	21	0	0	7	0	0	21	0	0
Transport charges	0	10	0	3	0	0	1	0	0	6	0	0
Cost per acre marketed	10	10	0	27	0	0	10	0	0	29	0	0
	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d
Cost per ton marketed	10	10	0	4	10	0	10	0	0	4	16	8
Market price per ton, say	12	0	0	5	0	0	12	0	0	5	0	0
Profit per ton	1	10	0	0	10	0	2	0	0	0	3	4
	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.
Profit per acre	1	10	0	3	0	0	2	0	0	1	0	0

Thus farm A. is able to put potatoes on the market at a lower cost than B., and would, at the prices assumed, make twice as much profit from potatoes as from wheat. Farm B. can produce wheat more cheaply than A., and would make twice as much profit from wheat as from potatoes.

(4) *Uncertainty of Returns.*—The variation in yield from year to year is in the case of potatoes rather high, being, according to the British Agricultural statistics, about 50 per cent. greater than in the case of wheat. Moreover, potatoes do not keep, at the longest, for more than eight or nine months, so that a surplus from one harvest is of little or no use in making good a deficiency from the next. The result is that prices fluctuate violently from year to year, making the crop a highly speculative one. The following figures illustrate the close dependence of the price on the annual production. The prices quoted are for first quality "Up-to-Date" (a standard maincrop variety), and refer to the periods October to May inclusive, following the respective harvests :—

Year	Total Yield (Great Britain). (Thousands of Tons.)	Average Price per ton. October to May.
		s. d.
1906 . . .	3428	77 6
1907 . . .	2977	94 0
1908 . . .	3917	53 6
1909 . . .	3674	63 6
1910 . . .	3477	81 0
1911 . . .	3825	74 3
1912 . . .	3179	92 3
1913 . . .	3865	69 3

In other countries, especially Germany, the manufacture of potatoes into non-perishable commodities, like starch and alcohol, provides an outlet for a considerable proportion of the potato crop and tends to steady the price from year to year. Similar manufactures have been established in Britain from time to time, but have not so far succeeded.

(5) *The Labour Requirement* of the potato crop is very high—four or five times that of a cereal. Other expenses, *e.g.* that of "seeding," being also high, potatoes can be most

profitably cultivated on the more fertile soils, where a high gross return can be obtained. On poorer and hence lower rented lands a return commensurate with the expense can rarely be obtained, and the farmer must look to crops that give moderate returns at a lower cost.

The labour distribution varies greatly according to circumstances. If conditions permit the cultivation of both early and late varieties, as for example in parts of Lincolnshire, the crop may give a very uniform distribution, planting extending from March till May, summer cultivation from April till July, lifting from June to November, marketing from June to May, and preparation of the land for the succeeding crops from July to April. If, however, one or other of the chief types (earlies, second earlies, or maincrops) is grown to the exclusion of the others, there will be periods of pressure at planting and harvest, especially the latter. The ordinary staff of the farm will usually be quite insufficient to lift the crop, so that a supply of casual labour becomes necessary. The amount of casual lobour that can be obtained often limits the acreage that can be grown. As regards the fitting in of potatoes in the general labour scheme, planting of earlies is generally done before the sowing of spring corn and that of maincrops between the seeding of the spring cereals and the preparation of the land for roots. Early varieties are usually lifted between the hay and cereal harvests, a period when on most arable farms there is little other urgent work. The harvest of second early sorts covers the period of cereal harvest, when the regular farm staff will generally be fully occupied, so that a complete additional staff may have to be secured for the potatoes. The maincrop harvest follows the cereal harvest, and must be completed before there is a likelihood of severe frost. Hence the rate at which lifting has to proceed, and therefore the quantity of casual labour that is necessary, depend on the length of time available between cereal harvest and the onset of winter. Broadly speaking, the work is more urgent, and the supply of casual labour must be greater in the north than in the south. The lifting

and storing of mangolds and sometimes the lifting of sugar beet is work that falls to be carried through in the same period of the year, whereas other root crops can be left in the field till later; for this reason, where the autumn is short, potatoes work into the labour scheme more satisfactorily where turnips and swedes rather than mangolds form the staple root crop.

(6) *Manuring.*—Potatoes respond to heavy manuring—the yield is highly elastic, as we say—and in particular they give a higher return than other crops (excepting possibly mangolds) from dressings of farmyard manure. Therefore the growing of potatoes is limited to a certain extent by the production of dung. Black fen land can, of course, be quite well farmed without dung, and in some coastal areas seaweed is used as a substitute for farmyard manure, and the potato area is kept up through its means. On early potato farms a similar purpose is served by feeding off catch crops of rye-grass, rape, etc., and in the moister districts temporary leys, through their contribution to the humus content, render heavy dunging less necessary. Broadly speaking, however, and in spite of the fact that potatoes can be continuously grown on the same land, the crop can rarely occupy more than 15 to 25 per cent. of the area of the farm.

(7) *The By-products* of the potato crop consist of small and damaged tubers which, failing starch or other manufactures, can only be used for stock feeding. In small quantities they can be profitably fed to cattle, but when the quantity to be dealt with is considerable it will be more economical to feed them to pigs, for which they may supply as much as half or more of the energy value of the ration. Where medium-sized tubers can be sold for seed purposes the amount of non-marketable material is comparatively small, averaging perhaps under 10 per cent. Where seed-sized tubers cannot be marketed the amount may rise to over 20 per cent.

Sugar Beet in Britain stands meantime upon a different footing from other market crops, as home grown sugar enjoys

a substantial Government subsidy.[1] Factories have been erected in various localities. They are most numerous in the eastern counties of England, but are becoming widely scattered throughout the more important arable districts. The crop is grown on contract for the factories, at an agreed price per ton, washed weight, delivered. Seed is supplied by the factory at approximately cost price, and dried pulp, in amounts corresponding to the quantity of beet supplied, is sold back to the growers at a preferential price. The following are the factors chiefly concerned in the economic success of beet growing.

(1) *Climate and Soil.*—The climate in the main arable districts, from Forfar to Devon, is quite favourable to beet culture. Farther north the crop does well in favoured localities. In the north the upper limit of profitable cultivation is probably about the same as that of wheat, viz., 500 to 700 feet above sea-level. So long as the soil has good depth, and is not sour, the crop can be profitably grown on a wide range of soils, from light sandy to heavy loam.

(2) *Distance from Factory and Transport Facilities.*—Proximity to the factory is a very important factor. A farmer within three miles of the factory might be able to deliver his beet at a total transport cost of 3s. per ton; another four miles from a station and fifty from a factory would have costs amounting approximately to 10s. per ton. Assuming a yield of 12 tons gross per acre, the net returns would be £4 per acre higher in the first case than in the second.

(3) *Labour Conditions.*—The hand labour requirement of the crop is high, and it is specially important that the operations of singling and lifting should be timeously performed. The availability of sufficient labour at the period in question is essential.

[1] The subsidy was granted in 1924 at the following rates, per hundredweight of sugar:—

1924-5 to 1927-8 inclusive	. . .	19s. 6d.
1928-9 to 1930-1	„ . . .	13s.
1931-2 to 1933-4	„ . . .	6s. 6d.

(4) *The Value of the By-products* (tops and pulp) under the system of farming followed has some importance. The value of tops is greater where sheep are kept, and that of pulp probably where dairy cows or winter fattening cattle are a feature of the farm.

The beet crop, while just as liable to failure from climatic causes as roots, is otherwise non-speculative since the price is agreed before the crop is planted. The capital involved is considerably lower than in the case of potatoes, costs of production being about £20 per acre.

Hay.—The cultivation of hay for sale is restricted, owing to the bulky nature of the crop, to areas that are fairly close to market. The chief market is, of course, for the feeding of city horses, and with the replacement of these by mechanically-driven vehicles the demand for hay has within recent years declined rather markedly. The future of horse transport in cities is still in doubt, but probably still more horses will be replaced, and the importance of hay as a selling crop will further decline. Apart from the question of proximity to markets, hay tends to assume the greatest importance on the heavier classes of land. This is partly due to the unsuitability of heavy soils for other market crops such as potatoes and sugar beet, and partly to the saving in cultivation costs effected by placing large areas under hay. On calcareous soils particularly in the south, clover, lucerne, and sainfoin can be profitably cultivated.

Of the minor market crops that are grown under farm or quasi-farm conditions, the most important are hops, mustard, and flax; vegetables such as cabbage, cauliflower, Brussels sprouts, carrots, and onions; and roots, clover, and grasses for seed.

Hops have a very heavy labour requirement—say, from double to treble that of potatoes—and ordinarily repay very heavy manuring and very intensive treatment generally. Hop-growing is a highly specialised business, and involves a heavy capital expenditure in the matter of poles, kilns, etc. Yield and quality are closely dependent on soil and climatic conditions, a deep medium or heavy loam or marl on an

open well-drained subsoil, abundant sunshine, shelter from strong winds, freedom from late and early frosts, and a dry picking season being all important. The result is that hop-growing in Britain is almost entirely restricted to two main areas, viz., Kent, Sussex, and Hampshire on the one hand, and Hereford and Worcester on the other. Even within these areas it is only in comparatively small districts that the crop occupies a large proportion of the land. Yields are exceedingly irregular, and prices vary within very wide limits.

Mustard (for seed) is a crop that can be most profitably grown on deep, fertile, rather moist soils. It requires to be harvested within very narrow limits of time and is easily damaged by bad weather, so that a dry harvest period is very important. The area required to supply market requirements is not very large—about half of one per cent. of the cereal area—and the crop is therefore closely restricted to a few specially suitable districts in the east of England, principally in Lincoln, Cambridge, and Norfolk.

Flax, in spite of a considerable amount of artificial encouragement during the war, does not appear to be destined to occupy any large place in British agriculture. The amount of labour required in pulling, retting, etc., is rather high, so that countries where unskilled labour is cheap are able to compete with British producers on very favourable terms. Moreover, the value of the clean fibre—averaging nearly £100 per ton—is so high as to make freight an almost negligible item in costs. The home producer therefore obtains little advantage from his proximity to the consuming centres. Grown for seed the crop requires little labour—less probably than the average cereal—but here again the product has a high value in proportion to its bulk, and hence tends rather to be grown in districts remote from markets where suitable land is cheap, *e.g.* in Argentina.

The growing of **Vegetables** as field crops is determined partly by proximity to market and partly by the occurrence of particular soil or climatic conditions. Illustrations are

to be seen in the wide cultivation of carrots in Lindsey, the Isle of Ely, and the East Riding; of onions and Brussels sprouts in Bedfordshire, of broccoli in Cornwall, and of celery in the Fens. Such crops are all expensive to produce, and are commercially successful only on very carefully chosen areas.

The principal **Seeds** produced in Britain (apart from cereals and pulses) are clovers, roots, and grasses.

Clovers are all dependent on insects for fertilisation, so that the seed yield is very closely governed by the amount of summer sunshine. They are also very susceptible to damage from wet weather at harvest. Consequently, the clover-seed industry is confined to the south-eastern counties, from Hampshire to Norfolk, and to certain small areas in the Severn Valley. Considerable quantities of clover seed are of course imported from France, the United States, Chile, etc., where climatic conditions are more favourable to production than anywhere in Britain. But the greater hardiness of the home stocks under their native conditions enables English seed to command a higher price than imported, and thus gives the home-grower a compensating advantage. Sainfoin seed is produced on the more highly calcareous soils in roughly the same areas as clovers.

Root Seeds can be grown over a somewhat wider range of climate, but give the most satisfactory results where the winter is fairly mild, the summer dry, and the soil deep and fertile. Lincolnshire, Essex, and Kent produce the main supplies.

Grass Seeds.—British requirements of grass seeds are at present met for the most part by imported supplies. The chief exceptions are the rye-grasses, of which considerable quantities are grown in Cambridge, Ayrshire, Stirling, and the north of Ireland, and timothy grown mainly in Stirling. The possibilities in regard to other species do not seem to have been fully exploited in Britain.

Live Stock.

The keeping of a certain amount of live stock is an economic necessity in practically all systems of farming. Even where farms are devoted primarily to the production of market crops, the utilisation of straw and the maintenance of the fertility of the land can only rarely be accomplished without animals. The two types of exceptions that occur in British farming are apparent rather than real. On the one hand, the fen farmer, who often keeps practically no stock, is steadily using up the reserves of humus in his soil; in certain cases the exhaustion of the humus reserves has already forced a return to normal methods, and in the others the same stage will be reached sooner or later in the future. On the other hand, we have suburban selling farms that carry no stock, but in such cases there is a supply of horse manure or equivalent material from the towns, so that the live stock, though not actually kept on the farm, is performing its normal function.

Again, it is possible to keep up the fertility of land by means of green manuring or by means of artificial farmyard manure, and in rare circumstances such methods may be economically sound. Ordinarily, however, it will be profitable to extract a part of the food value of all plant products before returning them to the soil.

The quantity of live stock that requires to be kept for the purpose of maintaining fertility varies with soil conditions. The rate of exhaustion of humus is highest on light, calcareous, or sandy soils, and lowest on heavy clays. Again, the amount of humus that is necessary to maintain productiveness varies, being lowest in the case of deep and naturally moist loams and highest in the extreme types of soil, such as thin, dry uplands, light sands, and sticky clays. Hence deep, strong, alluvial land can be farmed with a minimum of stock, whereas on thin, dry chalk a large proportion of the produce must always be converted into manure even where corn is looked to as the main source of revenue.

Thus even where stock has only an indirect function its importance may yet be great. But there are many circumstances in which live stock assumes the position of the primary department, where, that is to say, cropping is arranged to supply the needs of the stock rather than vice versa. In still other cases the two departments are mutually complementary and neither is subsidiary to the other.

Sheep are the most active type of farm stock, and therefore occupy a prominent position in most mountainous districts. Also, in part owing to this activity and in part to their small size and close grazing habits, they are able to thrive where cattle would starve. Consequently, on the poorer sorts of pastures, where the herbage is either sparse, or very short, or mixed with innutritious material and therefore requiring selective grazing, sheep form the most important class of stock. On the richer and more productive types of pasture their activity becomes a disadvantage. The habitats of the various wild species are chiefly districts of low rainfall, and sheep do not thrive if they are subjected to the combined effects of a wet climate and a retentive soil. Some English breeds, like the Ryeland and Romney Marsh, have, it is true, acquired a degree of resistance to wet conditions which is quite remarkable when they are compared, for example, with the Merino, yet even in Britain cattle tend to predominate wherever soil and climate combine to produce wet conditions. These facts are well illustrated by some of the English county statistics. Cheshire, with its rich, low-lying, and rather heavy soils, carries nearly three times as many cattle as sheep—the lowest proportion of sheep in Britain. Lancashire, with its greater proportion of upland grazing, has about five sheep to four cattle, while Westmorland has fully six times as many sheep as cattle. On the other coast, the Lindsey Division of Lincolnshire, with its low rainfall and lighter soil, has three times as many sheep as cattle, while in Northumberland, with its large proportion of upland as an additional factor, sheep are eight times as numerous as cattle; in Selkirk they are fifty times as many.

Sheep are more resistant to cold than other classes of stock, and under average British conditions can live outside and find a good proportion of their food on the land during winter, while cattle can do so only in our milder districts. This enables sheep-farming to be carried on with a minimum of buildings and with comparatively little labour, a point which is especially important on the poorer sorts of land where a non-intensive system must of necessity be adopted. In milder districts, such, for instance, as that of south-western Ireland, sheep lose the advantage of their cold-resisting powers; and, again, in countries with continental climates, such as Russia or Canada, where the ground is covered for a prolonged season with hard frozen snow, sheep have to be housed and hand-fed to nearly the same extent as cattle. The type of the British winter climate accounts in large measure for our relatively large national flock.

On arable land sheep are even more strictly dependent on soil conditions than on grass. Not only is wet clay soil injurious to the animals, but the treading and puddling caused by the latter is highly injurious to the soil. Thus Essex, with its predominantly heavy soils, has a ratio of cattle to sheep of 1 : 1·4, whereas in West Suffolk, with essentially the same type of climate but a larger proportion of light soil, the ratio is 1 : 4.

It is not only on the lighter, but also on the poorer types of arable land that sheep have great importance. Many of the poorer arable farms can be kept under cultivation only by adopting such a system as can be run with a minimum of costs. If reliance were to be placed on cattle for the maintenance of fertility, the labour costs, *e.g.* in carting roots from field to farmstead and carting back farmyard manure to the land, would preclude any prospect of profit. With sheep, on the other hand, produce can be fed off where it has grown, so that much labour is saved.

On the more fertile soils the disadvantage of this system is the lack of control in the use of the manure which it involves. Thus, for example, where potatoes, mangolds, and sugar beet are grown, these crops should have the bulk of the organic

manures, because they give a relatively high return from them and are at little risk of damage from over-manuring. But such crops cannot suitably follow turnips or swedes in the rotation, and it is with the latter that the saving of labour by feeding off is most marked. In such cases the folding of roots results in the application to the succeeding cereal of a heavy dose of manure, which may do harm rather than good; and at the same time deprives other crops of supplies of dung that would benefit them greatly.

On practically all farms there are supplies of food materials that can only be utilised by sheep—*e.g.* grazing on stubbles, winter grazing on cattle pasture, catch crops, etc. On large farms the utilisation of such foods may justify the keeping of a flock even where the general situation of the farm indicates cattle as the chief line. On smaller farms such by-products are usually better disposed of to flock-masters—*e.g.* for wintering hill sheep.

Sheep, as already indicated, require relatively little labour; but this labour must be of a highly skilled type, and the shepherd's calling is one of the most highly specialised in the industry. Hence sheep are most efficiently managed when the flock is sufficiently large (250 to 600 according to conditions) to provide employment for a full-time skilled herd. "The large farm is the mother of sheep husbandry" partly for this reason, and partly because the poorer sort of land, on which sheep are more particularly in place, is ordinarily worked in large units.

Sheep produce both wool and mutton, and either may form the primary product. Wool being non-perishable, and having, in proportion to its weight, the highest value among the commoner agricultural products, tends to become the main product in regions very remote from markets where land is very cheap—such, for instance, as the Australian "Back Stations" and the less-developed parts of Argentina. Mutton, on the other hand, while it can be transported for long distances at a moderate cost, commands the highest price when it is sold fresh.

The British producer is thus at an advantage, as compared

with competitors overseas, in the meat market, whereas he is on the whole at a marked disadvantage in the wool market. Under existing conditions, therefore, commercial sheep-breeding in this country means primarily mutton production, and wool is considered only in so far as it does not seriously interfere with the prime object. The breeding of pedigree sheep for export is, of course, a different matter, and here wool qualities may receive a relatively large measure of consideration.

The sheep industry exists in many different forms. The most intensive, suitable for the more fertile and higher rented lands, are the production of early lamb and the winter fattening of stores that have been bred and reared elsewhere. On poorer land, regular breeding stocks, producing principally store lambs, tend to be kept, and on the very poorest wether stocks are occasionally to be found. Various intermediate systems are adopted elsewhere.

Cattle form on the whole the most important class of farm stock. This arises partly from the variety of their useful products—beef, milk, butter, cheese, and leather—and partly from the large proportion of coarse and fibrous materials, such as straw, hay, inferior grass, etc., that may figure in their diet. It is true that pigs will convert certain classes of foods into meat much more economically than will cattle, but this applies to a limited number of materials of relatively high digestibility. It is true, also, as indicated above, that sheep may be more efficient meat producers where herbage is sparse, and that sheep, under British climatic conditions, require less labour and equipment because they do not need winter housing; but there are many farms that can be carried on without the aid of either sheep or pigs, and very few that can be run permanently without a stock of cattle.

Cattle tend to predominate under the opposite conditions to those mentioned under sheep. Thus we find cattle occupying the chief position on the heavier and moister types of grassland, where the herbage is abundant; under the wetter climatic conditions; and, as regards arable, on

the heavier, the richer, and the more intensively farmed lands. Generally speaking, if the sheep and pig stocks of a farm are determined on the principles set forth in the foregoing and the succeeding sections, the quantity of cattle stock will be determined automatically. The real difficulty arises in deciding the type of stock to be kept and the particular product that is to be exploited.

The production of **Milk** for direct sale is confined to districts within fairly easy reach of markets. Recent developments in the way of cooling plant, rapidity of transport, etc., have, it is true, markedly extended the zone in which market milk is produced, but the cost and speed of transport still constitute a factor of prime importance. Thus assuming an annual production of 240 gallons of milk per acre of land,[1] each penny per gallon of transport cost will make a difference of a pound per acre in the value of the land for milk production. It seems unlikely that overseas supplies of fresh milk will ever become a very important market factor, but imported dried and condensed milks enter into competition with the fresh product.

Milk production is most likely to be profitable, other things being equal, when a uniform output can be maintained throughout the year. This implies the maintenance of a fairly constant number of cows with arrangements for feeding them on full productive rations at all seasons of the year; which again implies, for maximum economy, a combination of pasture for cheap summer feeding and of arable products—roots, silage, corn, and litter straw—for winter maintenance. Purely arable dairy farming can only be successful on selected types of land, notably light soils in fairly moist climates. Grassland farms can produce summer milk very cheaply, but the maintenance of a corresponding winter supply can only be secured, at a reasonable cost, where large quantities of good meadow hay can be cheaply produced, and where concentrates can be cheaply bought. In respect of the cost of concentrates suitable for dairy cattle this country is on the whole favourably situated, since there is a large home

[1] This is a high figure.

production of by-products from the milling and oil extracting industries.

Cows, especially those of the smaller and more active breeds, are capable of quite a high measure of production on land where cattle do not readily fatten. Hence the dairy industry tends to become established on land of moderate fertility rather than in the very best pastoral districts. The selling of whole milk gives much more rapid returns than rearing or fattening, so that the amount of floating capital required is low and its turnover rapid.

Whole milk production is a business requiring more than the average amount of skill and close supervision; moreover, the handling and disposal of a small daily output is relatively costly. Hence milk production is not a suitable business to occupy a minor place in the farm economy. It tends rather, where it is taken up at all, to become the main object of the farm.

Cheese has something approaching ten times the value, weight for weight, of whole milk, and is, in the case of most standard varieties, practically a non-perishable commodity. The market is therefore open to world competition, and the industry tends to be carried on wherever natural conditions permit the production of milk at a cheap rate, and where land is of low value on account of its distance from markets. The natural conditions in question comprise a long, mild, and rather moist growing season, so that the cattle may be at pasture for the greater part or the whole of the lactation period, and preferably a mild winter, so that the cost of winter housing and feeding may be kept low. Cheese-making is ordinarily carried on for part of the year only—the season of cheap food. All the cattle calve down in spring, so that most of the milk may be produced during the grazing season, and so that the winter ration may be as light as possible. With moderately good market facilities, it is often most profitable to combine cheese-making during summer with milk-selling during winter, at which latter season the price obtainable for milk is usually higher. Cheese-making involves more floating capital than milk-selling, since produce

is not ordinarily marketed till it has matured, being then perhaps three or four months old.

Whey is a by-product whose utilisation is a matter of considerable difficulty. It contains fully one-third of the net energy value of the milk, and has, on the basis of composition, a value of ¾d. to 1d. per gallon; but its perishable nature and its very high water content reduce its usefulness where it is produced in large quantities. Limited quantities can be utilised for calf-feeding, and larger quantities—up to 2 gallons per 100 lb. live-weight—may be fed to pigs. Pig-feeding is therefore almost a necessary complement to cheese production. Some progress is being made with commercial processes for the extraction of milk sugar, etc., which may ultimately overcome the problem of disposal in the larger cheese factories, where it is most difficult.

The manufacture of **Butter** or the separation and sale of cream are alternatives to cheese-making. With milk of average composition the yield of butter may be taken at about 0·4 lb. per gallon as against 1 lb. per gallon, for ordinary hard cheese.[1] Since the average price of butter per pound is only about 70 per cent. higher than that of cheese, it follows that the direct return from butter at normal prices is about three-fourths of that obtained from cheese. Temporary fluctuations in the relative prices of course occur and must be taken into account. It should also be noted that local markets for fresh butter frequently offer a price considerably above the ordinary wholesale figure. Regarding cream, which is of undefined composition, no relative price figure can be given; but, for example, if cream containing 50 per cent. of butter-fat can be sold at 12s. per gallon, this would be equivalent to a return of 10d. per gallon for normal milk, or equal to 2s. 1d. per pound for butter.

Butter and cream give a quicker return than cheese and leave the producer with separated milk, which is a by-product of very much greater value than whey. On the basis of its energy value and protein content separated milk is worth

[1] See Appendix—Estimation of butter and cheese yields.

about twice as much as whey, and actually, owing to the fact that it can be fed in perfectly sweet condition, its value for many purposes is proportionately much greater than the difference in composition would imply. In particular, separated milk can be very advantageously used in calf-rearing and for pigs between one and three months old. Thus calf-rearing is generally and pig-breeding is frequently carried on in conjunction with butter-making or cream-selling. Butter and cream being comparatively perishable commodities, are subject, like milk, to seasonal variations in price; hence whereas cheese, as already noted, can generally be most profitably produced in pastoral districts, butter-making tends to be more profitable on mixed farms where production can be maintained during winter at a moderate cost.

Calf-Rearing.—It is generally recognised that, as regards dairy stock, there is a considerable advantage to be gained by the home-rearing of a sufficient number of heifer calves to maintain the establishment of milking stock. The number of heifer calves that must be retained annually for this purpose is about 20 or 25 per cent. of the number of cows in the herd, or approximately half the heifer calves born. As regards the purely beef type of cattle—the type in which the milk produced by the cow is no more than sufficient for the needs of the calf—rearing for ordinary commercial purposes is mainly confined to those lower-rented pastoral districts where, owing to a high rainfall, heavy soil, etc., the conditions are unsuitable for sheep.

Apart from these two somewhat special cases calf-rearing tends to develop in districts remote from markets where the land is of moderate quality and where soil and climate are ill suited to the production of marketable grain. Under intensive conditions, *i.e.*, on the better types of soil and near markets, the high rental of the land and the high sale value of whole milk make calf-rearing uneconomic. Thus in Cumberland and Westmorland cattle under one year outnumber the cows and heifers in milk, whereas in Lancashire and Cheshire the latter are four times as numerous as the former. In general, cattle-breeding is an alternative to sheep-breeding,

and will have the preference on the moderately fertile mixed farms where the soil is heavy or the climate wet. This is more fully discussed above, under sheep. Again, calf-rearing involves more labour and more individual attention than sheep-breeding, and hence is suited to the small farm rather than to the large one.

From the completion of weaning onwards cattle require comparatively little labour and individual care and may be quite as successfully reared by the large farmer as by the small; otherwise the same general remarks apply to the business of rearing during the latter stages as during the former. Where arable and pastoral districts occur fairly near together there is a considerable transference of cattle from the one to the other in spring and back again in autumn.

Summer fattening of cattle is generally carried on where highly productive and nutritious pasture, either permanent or temporary, is available. There is the alternative, it is true, of stocking such land with the largest and most productive types of dairy cows, as is done, for example, in Holland; but although the precise causes are not understood, pastures of the finest quality frequently give a relatively better return from beef than from milk. Cows will often give quite satisfactory yields on land where cattle fatten only very slowly, and hence, where the area of specially rich pasture is limited it tends to be set aside for fattening. Soiling has a limited application in summer fattening of cattle, because it adds rather a heavy labour expense in a department where the gross returns are normally not very high.

The Winter Fattening of cattle provides on the whole the most convenient method for disposal of straw and for its conversion into the best quality of farmyard manure. Risks are comparatively small, and individual care and attention are less necessary than *e.g.* with dairy cows or calves. Hence, on the large arable farm, where the main income is derived from market crops, where live stock as a whole occupies a secondary position in the farm economy, and where only a winter stock is carried, fattening cattle generally form the bulk of the live stock. These conveniences

have had the natural result of lowering returns from winter feeding. The price of beef shows no seasonal variation corresponding to that of milk, and in fact is oftener lower for winter fattened animals than for summer-fed. On the average the highest prices for beef obtain in June and July and the lowest in autumn and early spring. Broadly speaking, winter fattening of cattle will be carried out only where other methods of disposal of by-products are not practicable.

It is fairly generally recognised that roots and straw in certain districts have a distinctly higher fattening value than in others. In particular, the north has an advantage over the south in this respect, so that the winter-feeding industry increases in importance from the south of England to the north of Scotland.

Pigs.—It has been already pointed out that pigs have a special value in the utilisation of certain by-products from other departments, notably whey in cheese dairies, and unmarketable potatoes. Consequently we find a large pig population in counties like Cheshire and Wigtown on the one hand, and in the Holland Division of Lincolnshire on the other.

There is a further connection between the proportion of arable land and the ratio of pigs to other stock—due of course to the fact that grass forms a food complete in itself for cattle and sheep, whereas pigs, in so far as they are kept on home-produced food, require a large proportion of grain, potatoes, etc. Thus Suffolk, Essex, Cambridge, and Norfolk have a much higher pig population, in proportion to other stock, than Devon and Cornwall.

Climatic conditions also play a part. In exposed situations and in cold and damp climates pigs suffer more than cattle and sheep. Hence, broadly speaking, the density of the pig population decreases, in Britain, from south to north. Lastly, proximity to sources of various industrial by-products—*e.g.* milling offals, distillery and brewery by-products—and to supplies of waste materials from shops, hotels, and households, is of considerable advantage. Therefore pigs tend to concentrate in certain industrial districts and in suburban areas generally.

Owing to the relatively quick rate of reproduction, the pig population of this and other countries is subject to rather marked fluctuations, which cause corresponding price changes. When prices are low breeding operations tend to be unduly curtailed and the population falls considerably. This produces a rise in prices which leads to some over-production, followed by a fall in price. The average time covered by one of these price cycles is between four and five years, so that the common saying "two years up and two years down" is not far from the truth. The home pork market is at present protected by disease regulations, but the bacon market is exposed to competition from Holland, Denmark, Canada, and the United States, where conditions are often more favourable than those of the home producer. The best class of British bacon and hams do, however, command higher prices than the best imported. The demand for pork is a seasonal one. Consumption is at its highest in December and January, and the numbers marketed weekly during this time are normally nearly twice as great as those for July, which are the lowest. Even with the smaller numbers sold, the price generally tends to sag during the summer months, especially during June and July. The average difference between December and July prices is about 10 per cent.

The pig industry can be quite economically conducted on a small scale and can be efficiently carried on with labour other than that of able-bodied men. It is therefore a suitable business for the small holder, and its importance tends to be greatest on small farms. This is illustrated by Vaughan's figures for the Cotswold area:—

Size of Farm.	Pigs per 100 Acres.
Over 500 acres . . .	15
300-500 acres . . .	22
100-300 „ . . .	30
Under „ . . .	77

Horse-Breeding may be carried on in either of two ways. On the one hand mares may be maintained for breeding only, and on the other hand they may be utilised for ordinary farm work, with more or less brief intervals of rest during the time when they are rearing foals.

Horses breed much more slowly than other live stock, the average proportion of females bearing live foals being probably not much over 50 per cent. annually. It is obvious, therefore, that maintenance of the breeding animals must add greatly to costs where other uses for them cannot be found. The smaller sorts of ponies and also light-legged horses such as hunters, which cannot well be employed in farm work, have necessarily to be bred on this system; breeding of such can generally prove profitable only under very extensive agricultural conditions, where maintenance charges are low. Pony-breeding is confined to mountain and moorland districts, while the larger types are bred chiefly in the better pastoral districts far removed from markets, where rentals are low in relation to the natural fertility of the land. The breeding of light-legged horses is sometimes taken up without a view to pecuniary profit, and returns tend to be reduced from this cause. Some special districts, like the limestone areas in Ireland, produce animals of exceptional size and strength of bone, and it is only in these that hunter-breeding becomes an important commercial enterprise.

For the breeding of heavy horses the chief essentials are a fair measure of employment for the mares in agricultural work, along with a fairly large run on pasture for the young stock. It is therefore on mixed farms that horse-breeding is most in place.

The seasonal distribution of the work is another factor of some importance. If this is very uniform the tendency will be against breeding, for breeding animals would then either be kept over and above the normal horse establishment, or else the mares would have to be worked while suckling, and the foals would suffer in consequence. On the other hand, if there is a season of comparative slackness in

horse labour, as frequently happens on mixed farms between root seed-time and cereal harvest, a proportion of breeding mares may be kept without adding materially to the total horse requirements of the farm.

It is desirable that the breeding mare should be of somewhat greater size and strength than a non-breeding animal for the same work, in order that the combined strain of work and breeding may not be too severe. On the heaviest arable, on steep land, or where there is an abnormal amount of heavy carting to be done, horse-breeding will generally not be attempted.

A mild winter climate is of some advantage in lowering the cost of wintering young stock. Returns from horse-breeding are at the best rather irregular, so that the industry is suited to form a minor rather than a main department of the farm. Its scope, too, is limited more or less by the number of horses that can be economically employed in work.

Poultry forms an important department on many types of farm; and although the technical aspects of poultry farming are not dealt with in this book, it is desirable that something should be said regarding the position that poultry may occupy in the general farm economy.

Fowls are capable of utilising certain by-products that would otherwise be lost. For example, as gleaners of cereal land after harvest, they are much more efficient than either pigs or sheep, and they may thus be kept at very little outlay for two or three months of the year. In the utilisation of unmarketable grain they are probably quite as efficient as other stock, and on many types of pasture land they are able to pick up a proportion of food which is not available to other animals. Since eggs form the most important product, and since these show very large seasonal variations in price, it follows that poultry are most successful, other things being equal, under conditions favourable to winter egg production—*i.e.*, in milder districts at fairly low elevations and in fairly well-sheltered situations.

While the labour involved is very considerable, most of it

is of a light nature, so that the industry can provide employment for labour that cannot otherwise be profitably employed. If skilled and interested management can be secured, poultry can be profitably run in small units and is relatively important on small holdings. On medium and large farms the best course is frequently to make the unit large enough to provide full time employment for one or more special workers.

Pedigree Stock Breeding is governed by somewhat the same conditions as those set forth above for commercial stock, but two or three other considerations must be borne in mind. A very considerably larger amount of capital is involved, partly because the individual animals are more valuable and partly because returns are less certain. Moreover, since pedigree breeding, especially with certain breeds, tends to become a hobby with wealthy people, there is a continual risk of overproduction of animals of moderate merit; hence a high degree of skill and expert knowledge are necessary to financial success. On the other hand, the maximum possible returns are far greater than those from ordinary commercial stock, so that there is more scope for skill and enterprise.

The Production of Food for Stock.

There remain to be discussed questions regarding the methods to be used in the production of food for stock.

Winter Food.—The table on next page expresses the yields of the more important feeding crops in terms of units per acre of dry matter, starch equivalent and protein equivalent.

As regards the total production of net-energy (starch equivalent) it will be noted that cabbage, kale, and mangolds head the list. These crops are at the same time probably the most expensive in labour, manure, etc., and therefore they tend to be those grown on the best land and in the vicinity of towns where the animal husbandry is of a very intensive form, *e.g.* milk-selling. At the opposite end of the scale stands meadow-hay, the least costly crop to produce, but giving the lowest yield. Hay thus forms the staple

winter food wherever extensive methods have to be adopted —on poorer soils and in remoter districts.

	Dry Matter per Acre Units.[1]	Starch Equivalent per Acre Units.	Starch Equivalent as Percentage of Dry Matter.	Protein Equivalent per Acre Units.	Albuminoid Ratio.
Turnips (15 tons) . .	130	75	58	6	1 : 9
Swedes (14 tons) . .	160	98	61	10	1 : 7
Mangolds (19 tons) . .	250	133	53	8	1 : 14
Cabbage (25 tons) . .	275	175	64	22	1 : 6
Kale (20 tons) . . .	285	180	63	26	1 : 5
Silage—Oat, Bean and Vetch (8 tons)	240	104	43	13	1 : 7
Meadow Hay (24 cwt.) .	100	37	37	6	1 : 5
Clover Hay (30 cwt.) .	125	48	38	10	1 : 5
Lucerne, green (8 tons) .	190	72	38	20	1 : 3
Oats, Grain (14 cwt.) .	60	42	70	5	1 : 7
Straw (22 cwt.) .	75	20	21	1	1 : 39
Total Crop (36 cwt.)	155	62	40	6	...
Barley, Grain (15 cwt.) .	64	54	83	5	1 : 10
Straw (15 cwt.) .	63	14	22	0·5	1 : 52
Total Crop (30 cwt.)	127	68	53	5·5	...
Beans, Grain (16 cwt.) .	70	53	76	16	1 : 2
Straw (24 cwt.) .	103	23	22	2	1 : 19
Total Crop (40 cwt.)	173	76	43	18	...
Potatoes (6 tons) . .	143	108	78	4	1 : 16

[1] The Unit is 1 per cent. of a ton, *i.e.* 22·4 lb.

The relation of energy value to total dry matter (column 3) has an important bearing on the value of feeding stuffs, varying with the type of animal to be fed and the other feeding stuffs that are to be used in conjunction with the one in question. Roughly speaking, the starch equivalent of the ordinary types of production rations should bear the following proportion to the dry-matter content, viz., for pigs, somewhat over 75 per cent.; for sheep, 50 to 55 per cent., and for growing and fattening cattle, 40 to 50 per cent. Thus, for pigs, grain (especially barley) and potatoes are the only materials that can be largely used in compounding satisfactory rations. Kale and cabbage can be employed to some extent if they are balanced with more concentrated sources of energy. Hay alone is sufficiently concentrated for only the lowest types of productive rations in cattle—for full production it must be supplemented with roots or

concentrates or both. Silage is little better from this point of view. If large quantities of straw are to be utilised for feeding (*i.e.*, are to yield energy in saleable form) considerable quantities of roots or grain or both must be used in conjunction. Silage cannot be used as a substitute for roots in such cases, because if sufficient silage is fed for full production, the cattle will consume little or no straw. Under the less intensive systems of farming the object of winter feeding may sometimes be maintenance only and not production. Here the question of the ratio of energy to dry-matter is of much less importance, a relatively bulky ration being desirable. Where the protein supply is of importance (as, *e.g.*, notably on dairy farms) the cost of production of this constituent becomes a matter of moment. The cost is naturally lowest where leguminous crops are the source, and hence legume hays, silage, and beans have a special value to the dairy farmer. On fattening farms the choice will generally fall to the cheapest source of net-energy, often, for example, roots and straw. The foregoing general facts being borne in mind, the choice of feeding crops must depend on a consideration of soil, climatic and labour conditions.

Mangolds have a high maximum yield and are therefore specially suited to the better soils; they thrive best where the amount of sunshine is high; they produce relatively heavy yields on deep and rather heavy soils. The labour requirement is high; the growing season is long and the crop is very susceptible to frost damage, so that the seasons of sowing and harvesting are restricted within rather narrow limits—*i.e.*, little latitude is allowed in the seasonal distribution of labour. The last difficulty is of course most severely felt in the northern districts where the season is short. In these districts, too, the crop competes for labour with the potato crop, where the latter is grown, both in spring and autumn.

Turnips and Swedes are relatively more successful on the poorer soils; they require more rain and less sun; they are specially dependent on fine tilths at seeding,

and hence are unsafe on the heavier soils and in districts liable to summer droughts. The growing season is shorter and the susceptibility to autumn frosts much less, so that they are, relatively to mangolds, more successful in the north than in the south.

Apart from the question of the direct effect of soil and climatic conditions there is a connection between the proportion of mangolds to turnips and swedes with that obtaining between cattle and sheep. This is of course on account of the fact that turnips and swedes can be folded, and the cost of feeding to sheep thereby reduced. There is a considerable advantage to be gained by growing both crops, firstly because of the better labour distribution that can be obtained by so doing, and secondly, in order to obtain both autumn and spring keep, mangolds being unsuitable for the former purpose, but much superior for the latter.

The following table of county statistics illustrates some of the foregoing correlations :—

County.	Annual Rainfall. Inches.	Mean Daily Sunshine. July Hours.	Predominant Soil. Type	Ratio Cattle to Sheep.	Percentage of Root Area under		Yield Tons per Acre.	
					Mangolds.	Turnips and Swedes.	Mangolds.	Turnips and Swedes
Isle of Ely . .	24	6·7	Fen	2 : 1	92	8	26	15
Essex . . .	23	7·0	Heavy	1 : 1½	65	35	17	12
Cheshire . .	32	6·0	,,	3 : 1	38	62	21	17
Berkshire . .	32	6·4	Chalky	1 : 2	32	68	18	12
Lancashire . .	35	6·0	Loam	1 : 1¼	24	76	19	18
Dorset . . .	38	6·8	Light Chalky	1 : 2½	16	84	21	12
Northumberland	32	5·3	Loam	1 : 7	2	98	15	15·5
Aberdeen . .	30	5·0	,,	1 : 1¼	0·2	99·8	12	15

All root crops are of course very costly in hand labour, and hence the root area is dependent on the relationship between wages and live stock prices. A rise in wages or a fall in cattle and sheep values causes a decline in the cultivation of roots.

Cabbages, being specially suitable for autumn feeding, and having roughly the same soil and climatic requirements as mangolds, are most extensively grown under the same conditions as the latter crop. They are specially valuable where pastures are liable to fail early, *i.e.*, in dry districts, and where highly intensive feeding is carried on—*e.g.* on dairy or pedigree stock farms. Their value for pig-feeding has been already noted.

Silage is of greatest value on the extreme types of soil where either a tilth for roots is difficult to secure or the latter crop is liable to fail through summer drought. It is also worthy of consideration in the wetter and later districts where haymaking and cereal harvesting are frequently expensive and unsatisfactory.

The labour requirement is much less than that of roots but greater than that of hay. The labour is required, for sowing, at roughly the season of cereal seeding, so that the introduction of silage may aggravate a congestion of work at that time. The harvest period in the case of spring-sown crops falls between that of hay and cereal crops, at a time when other work is frequently not pressing. The harvesting of autumn-sown crops may clash with haymaking. Silos are in place on farms where stock is the main department rather than on those where grain-growing is the chief object. They are probably of greatest value on dairy farms.

The capital expenditure for ensilage on a moderate scale may be reckoned at about £20 per acre of silage grown, giving an annual charge of fully £1 per acre to cover interest and depreciation.

Hay.—Apart from silage, hay forms the chief alternative to roots and straw as the basis of winter feeding. Hay is of course relatively largely grown in pastoral districts, *i.e.*, in regions of heavy soil and of fairly high rainfall, whereas roots are relatively more important on the lighter soils and the drier climates. Thus in Cheshire and Warwick there are approximately 8 acres of hay grown to each acre of roots, whereas in Cambridge there are only 2½, and in Norfolk only a little over 1. Where roots are specially reliable and

of good feeding quality, *e.g.* in Aberdeen, the area of roots exceeds that of hay.

Hay can of course be made from a variety of plants, from annuals such as peas and oats to perennials like lucerne and timothy. Of the plants grown in the more purely arable districts, *i.e.*, in leas of short duration, clover predominates in drier and rye-grass in the moister districts. For semi-permanent meadows lucerne is most valuable in dry and sunny districts, provided the right type of soil is available. On heavy land in districts of moderately high rainfall timothy is highly productive. Permanent meadows have already been discussed in Chapter I. of this section.

The labour required for the hay crop is concentrated in a short period but is light provided the available labour-saving machinery is used. Where the area is large in proportion to other crops, more or less casual labour must be obtainable for the haymaking season. A good deal may be accomplished to ease the labour situation by grazing the crops for varying periods in the spring and also by growing a variety of different types. Rye-grass and clover, for instance, are ripe for cutting considerably before timothy or meadow-hay.

Oats.—Cereals must almost necessarily occupy a fairly large place in any system of arable farming because of their low cost of production when grown in conjunction with other crops. Moreover, a certain proportion of concentrates must be employed in compounding most types of rations, and the cereal grains form, broadly speaking, a good and cheap source of energy in concentrated form. Ordinarily the practical question for the arable farmer is not whether cereals shall be produced, but whether the grain grown shall be consumed on the farm or sold and replaced by purchased concentrates. The answer to this depends on the relative market values of home grown grain and market concentrates and on the transport costs involved in making the exchange. Hence in the later and wetter districts where the crop is of relatively low market value, and again where markets are not easily accessible, it will often be profitable

to use the home-produced grain for feeding. Oats form by much the most important cereal for stock-feeding purposes. For horses, cattle, and sheep the grain forms a healthy, palatable, and broadly speaking a well-balanced food, though for pigs the fibre content is somewhat too high. The straw yield is relatively large and its feeding quality, particularly when the crop is grown in the cooler and moister districts, is high.

Barley grain has a higher energy value than oats; it is less suitable for horses but more valuable for pigs. The straw is less in yield, and perhaps on the average of lower feeding value, though in the drier and sunnier districts, where oats do not flourish, the latter statement does not hold good. Broadly speaking, barley is grown as a substitute for oats in the thinner and drier soils and in the drier districts, and again in regions very far north where the growing season is very short. Where the end in view is stock food, the varieties that are cultivated in both cases are frequently different from those that are preferred where marketable grain is the object. In oats, particular attention is paid, in feeding varieties, to the yield and quality of straw, and in barley a high nitrogen content should be aimed at as opposed to the low nitrogen content desired for malting. Six-rowed winter and four-rowed early maturing spring varieties are those commonly cultivated for feeding.

Wheat is little used for feeding, except in the case of poultry, the grain being rather unsafe for most classes of stock, and the straw having a very low net-energy value. Rye is still less desirable from both points of view. Either crop may, however, be used in the green state for soiling purposes.

Beans, as appears from the table on p. 655, are specially valuable on account of their high production of protein. They are therefore rather largely grown on dairy farms wherever the soil is adapted to their needs.

Total requirements in the matter of winter foods depend of course on the length of the growing season. They are, for example, relatively high in the north-east and low in the south-west of Britain.

Summer Food.—It has been already mentioned that, on the whole, stock can be maintained more cheaply on pasture than on arable crops during summer; whereas in winter arable land products will usually form the most economical source of food. Hence there is a considerable migration of stock from pastoral to arable districts in autumn and back again in spring. Even in mainly arable districts where it is necessary to maintain stock (such, for instance, as dairy cows or breeding flocks of sheep) during summer, it will generally be found that for part of the growing season pasture will form the cheapest food. The system of pasture management that is calculated to give the best returns depends on conditions. The poorest mountain pastures will not give an adequate return either for fencing or manuring, or indeed for anything but the least costly improvements. Grass that is worth a few shillings per acre is generally most economically managed in large enclosures, and will rarely pay for any manures other than cheap mineral substances like mineral phosphate or slag. Fattening pastures are always intensively managed from the labour point of view, but there is often little scope for improvement by manuring. The new intensive system, involving rotational grazing and heavy nitrogenous manuring, offers the best prospects of success on grassland of moderate fertility, particularly where, owing to its economic situation, it commands a relatively high rent.

Arable forage crops grown for soiling or for folding may be used in greater or lesser measure as a substitute for pasture.

Generally speaking, cultivated forage crops are considerably more productive than pasture, but the cost of production per acre is higher. Hence the cultivation of the former will tend to be carried on where the natural and economic conditions favour intensive methods, *i.e.*, near markets and on the better sorts of land. Generally, it is only under such conditions that pasture forms no part of the summer food. Apart from this a regular supply of food can only be assured on the lighter classes of soil and

in districts of fairly high and evenly distributed rainfall, because elsewhere it is impossible to accomplish the necessary cultivations at the right seasons or to rely on the regular germination of the seeds sown. The cultivation of perennial forage crops, such as lucerne, which are much less dependent on regular rainfall than annual forage crops, is of material assistance in a summer soiling or folding system. A silo, in which surplus produce may be stored against seasons of scarcity, is also of great advantage. A short growing season is a further obstacle to the cultivation of forage crops, because under such circumstances full production can only be assured by sowing all crops in spring and harvesting in autumn. Forage crops for summer feeding are therefore much more widely cultivated in the south than in the north—as compare, for instance, Wiltshire with Aberdeenshire.

As a supplement to pastures, particularly during the spring and autumn seasons, arable forage crops are of much greater importance. In the milder districts the growing of autumn-sown catch-crops, such as rye, crimson clover, winter vetches, etc., makes possible the feeding of full productive rations during the transition period from winter feeding to pasture. Again, especially in dry districts where pastures fail early in autumn, spring-sown forage crops such as rape, kale, spring vetches, early cabbage, maize, etc., enable full production to be maintained until regular winter crops are available. This is of course possible on almost any type of arable soil, as witness the cultivation of many of the crops named on the heavy soils of Essex.

CHAPTER III

SYSTEMS OF FARMING

I.—Co-ordination of Departments.

SUPPOSING that one has formed an opinion regarding the commodities that might be economically produced under any given set of conditions, one's next problem is that of fitting together the separate departments into a general scheme that can be economically run as a whole. It is necessary to state some of the guiding principles that have to be kept in mind when this is being done.

Seasonal Distribution of Labour.

Wages, generally speaking, form the largest single item of expenditure, and it is convenient to take the labour organisation as the starting point in constructing the farming system. The essential ends to secure are that there shall be productive work for all the labour that is employed at any particular season, and that sufficient workers shall be available to perform in due season all the work that falls to be done.

Under a majority of circumstances the cost of labour in relation to its quality is lowest when constant employment is given. Exceptions are to be found where other industries, such, for example, as forestry or fisheries, offer seasonal employment; under such circumstances it may happen that labour can be obtained at a cheaper daily rate if the labourer is offered a seasonal rather than a yearly contract. But in general, casual labour is relatively expensive, and in many cases skilled casual labour is virtually unobtainable at those seasons when it would be required. The working of overtime

in busy seasons is of course another alternative, but overtime scales of pay are naturally higher than ordinary rates, and the working of much overtime leads inevitably to some loss of efficiency. Hence the seasonal distribution of farm work must always receive careful consideration, and seasonal demands must be levelled up to such an extent as will make the labour most productive in relation to its cost.

The same considerations apply to horse labour. Occasionally remunerative seasonal employment for horses may be found outside the farm, *e.g.* in contract carting. Again, the establishment of horses may sometimes be profitably altered, from one season to another, by purchase and sale; but in general it will be most economical to keep the establishment of horses constant throughout the year, and the ideal to be kept in view is their regular employment in moderate work at all seasons. This object must, of course, be given no more than its due weight in the general scheme of organisation and, in fact, the number of horse working days is found to vary, on well-organised farms, within wide limits—say from 180 to 280 days per annum. The partial substitution of tractors for horses and the employment of a proportion of breeding mares are, as previously mentioned, possible methods of securing economy of horse labour.

The operations of the farm, regarded from this point of view of the seasonal distribution of work, may be roughly grouped in four categories, viz.:—

(1) Such as have to be performed regularly, as a matter of daily routine—*e.g.* milking and the feeding and tending of live stock.

(2) Such as can be efficiently or successfully performed only within narrow limits of time, and may be, in addition, dependent on weather conditions—*e.g.* hay-making, cereal harvest, mangold and potato raising, seeding of spring crops, singling of roots, etc.

(3) Such as fall to be carried out at certain approximate periods of the year, but are not strictly limited as to time and weather — *e.g.* winter ploughing, storing of swedes, carting of farmyard manure.

(4) Such as can be equally well performed at any season or in any weather—*e.g.* road mending, building repairs, the overhauling of implements, machinery and other equipment, and indoor work generally.

Operations in the first category present little difficulty except the unavoidable one that they have to be performed seven days a week; the last group usually presents no difficulty at all. It is the other categories, and particularly the second, that must receive careful attention when the general system is being worked out. Broadly speaking, a large proportion of any one crop leads to difficulty in organisation because there is usually an optimum time for seeding, harvesting, etc., and hence too large an area will involve either the employment of casual labour at generally high rates, or the spreading out of the necessary work beyond the desirable time limits. As an example of the working out of the seasonal distribution of labour we may take an east coast arable farm growing a fair variety of crops and farmed, say, on the East Lothian six-course rotation of (1) spring oats, (2) maincrop potatoes, (3) winter wheat, (4) turnips and swedes, (5) barley, and (6) hay.

The following might be approximately the normal dates of the more critical operations:—

Oat sowing	15th to 31st March.
Barley sowing	1st March to 15th April.
Potato planting	1st April to 1st May.
Root sowing	1st to 20th May.
Root thinning	1st to 25th June.
Hay-making	25th June to 10th July.
Summer cultivation of potatoes and roots	Till 20th July.
Wheat, barley, and oat harvest	10th Aug. to 25th Sept.
Potato lifting	1st to 20th October.
Wheat sowing	25th Oct. to 30th Nov.

While the labour distribution obtained on this system is, broadly speaking, very satisfactory, the following disadvantages and difficulties fall to be noted:—

(1) There is a large preponderance of spring-sown crops, with the result that there is frequently great pressure of

work in April. Late sowing of barley is a common consequence, particularly where roots are fed off late. Casual labour must generally be obtained for potato planting, but this need be neither skilled nor able-bodied.

(2) In the event of delayed germination of the roots, root thinning may clash with hay-making. Further, successive sowings of roots may "come to the hoe" simultaneously, and casual labour may be required to ensure timely singling.

(3) There is liable to be a gap between the completion of summer cultivations and hay harvest on the one hand and the commencement of cereal harvest on the other; all the cereal crops tend to ripen together, making the harvest a time of great pressure. The introduction of a proportion of early potatoes or of spring-sown silage crops would bring useful work into the slack period mentioned, without, however, easing the problem of the cereal harvest. The substitution of winter for spring oats serves both ends, but apart from the fact that winter oats are not entirely reliable in the northern areas, the preparation of the land for this crop involves the loss of the hay aftermath.

(4) The late ripening of the potato crop, taken in conjunction with the possibility of severe early frost, makes the potato harvest an exceedingly pressing business, and there is frequently great competition for the available pickers. By following the potato crop with wheat, the seeding of the latter crop is liable to be unduly delayed. Occasionally no opportunity of sowing wheat occurs, and there is a certain derangement of the system through the substitution of a spring cereal.

Difficulties such as those in the foregoing example are found in most systems. Not only is it impossible to plan a perfect distribution of labour that would adapt itself to all probable climatic variations, but the question is only one of many that have to be considered, and imperfections in one direction must be accepted if there are compensating advantages in some other.

Fig. 63 illustrates an actual case of seasonal distribution

of labour on a mixed farm in the Midlands. The total area was 540 acres, of which, in the year in question (1922-1923), 290 acres were under arable crops and 250 under permanent grass. On the acreages of the several crops grown and the numbers of stock kept, the labour requirement may be estimated, from the average figures given on p. 621, at just over 5000 man days, equivalent to the full time of

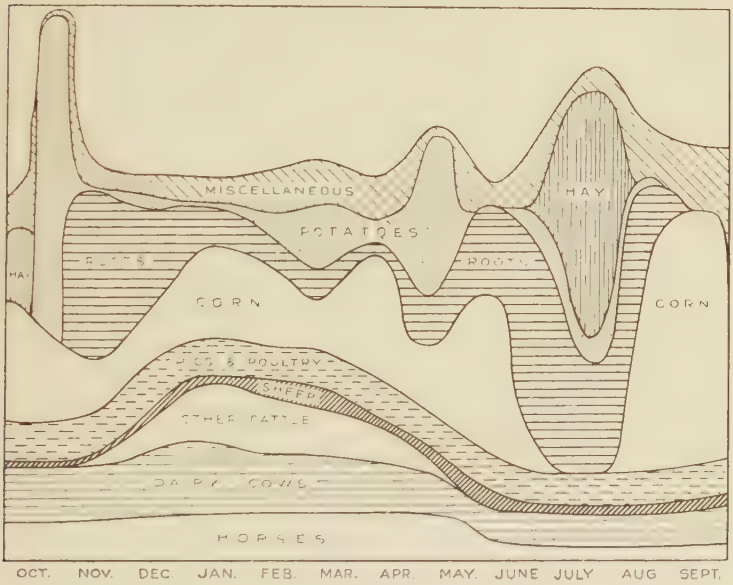


FIG. 63.

seventeen men. The staff regularly employed was sixteen men and two boys.

The chart shows that the labour distribution was fairly even, the extra time devoted to the live stock in winter being roughly balanced by the greater requirements of the arable in summer. Miscellaneous labour was fairly uniform throughout, showing that there was no period when it was found necessary to resort largely to "fill time" jobs. A large number of casual hands had to be employed for a short time in lifting potatoes, but such employment is generally unavoid-

able. There were peaks too at the time of potato-planting (April-May), and again in July when root thinning clashed with hay-making. Broadly speaking, however, the organisation was successful from one point of view, that is to say, productive work was available for the whole staff at all seasons of the year.

Judged by the other test—the timely performance of important work—the organisation is seen to have been faulty. Potato planting was not finished until mid May; in May and June a great deal of time had to be devoted to the weeding of corn crops, with the result that hay-making scarcely began in June. The latter operation continued till the beginning of August, when cereal harvest started. Summer tillage of roots continued till the end of August, long after harvest was in full swing, and the harvest itself was not completed at the end of September. Moreover the number of working hours recorded is consistently higher than normal. It is clear that there was always more to do than could be comfortably managed, and that overtime must have been the rule rather than the exception. Either, then, the regular staff was inadequate, or else the management of the work was inefficient.

Labour distribution is affected not only by the proportions of the various crops grown, but also by the order of their succession in the rotation. Obviously one must aim at allowing sufficient time between the harvesting of one crop and the sowing of the next for the necessary cultivations, with a certain margin against the possibility of unfavourable weather. For example, where roots are left on the land for winter folding, the choice of a crop to succeed them is limited to such as may be sown fairly late in spring; or again, if aftermaths are wanted for autumn grazing they cannot, in many districts, be followed by winter wheat.

Weed Control.

A second requirement that any permanent scheme of farming must fulfil is that it should provide means for the control of weeds. A clean farm is one of the chief marks

of an efficient farmer, but this end, like others, must be attained with due regard to economy. Apart from special measures that may be employed against particular species, such as spraying of charlock, there are four chief methods of weed control:—

(1) The use of smother crops. Here the object is to suppress the weeds through the agency of the competition of the crop. Silage crops and late potatoes are perhaps the most useful from this point of view because, with such, a dense, luxuriant vegetative growth is desirable in itself. On the other hand barley, for example, does not lend itself to such use, because great vegetative luxuriance is incompatible with high quality of the produce. Obviously the greatest degree of reliance can be placed on this method where the land is fertile, where the moisture supply is fairly abundant, and where, owing to favourable economic conditions, a somewhat intensive system is justified. On poor, dry soils the method has a very limited application.

(2) The alternation of arable crops with grass, and of hay with pasture. The particular weed species that flourish in the one type of environment generally die out more or less rapidly in the others. Thus charlock and poppies are weeds of cultivated fields; yellow rattle and soft brome of meadows; and ragwort, daisies and plantains of pastures. Alternate husbandry is generally to be regarded only as an aid in weed control, other and more active measures being usually necessary in addition. Its most striking benefits are to be seen in certain clay districts in Scotland, where it has been found possible to work on a rotation of two or three cereal crops followed by a period of perhaps five to eight years of timothy hay (the aftermaths being grazed) without the introduction of a fallow.

(3) The inclusion of fallow crops in the rotation. This must normally be regarded as the chief method on all the lighter and medium soils in this country—on all soils, that is to say, where potatoes, roots, cabbages, etc., form reasonably reliable crops. Any crop may, of course, receive a certain amount of intercultivation, but it is only where the individual

plants are fairly large, permitting the use of horse implements between them in their early stages, that such intercultivation can be carried out at a moderate cost. At the best the amount of hand labour required is heavy, and it is only where intensive systems are justified that frequent fallow crops can be profitable. Broadly speaking, a proportion of one cleaning crop to two cereal crops may be expected to provide sufficient opportunities for weed suppression; and a less proportion than this will usually make for difficulty unless use be made of some of the other methods of weed suppression. Much, however, depends on the type of soil, well-drained and fertile clays being notably less liable to weed infestation than sandy or chalky soils.

(4) Cultivation in the absence of a crop. Such cultivation may be carried out in the same season that an ordinary crop is grown (spring or autumn cleaning); it may extend over a part of the ordinary growing season, the remainder being occupied by a quick-maturing crop such as a single cut of hay, or a green forage crop (bastard fallowing); or finally, it may extend over a full season (bare fallowing). The first of these methods is obviously limited in its application by climatic conditions. In the colder and wetter districts the ordinary cereal crops must be sown as soon as the ground becomes workable in spring, and are harvested so late that little or no autumn cultivation is possible; whereas in the south, where harvest is early, a great deal of cleaning may be accomplished in autumn.

Bastard fallowing involves the sacrifice of part of the summer season. Hence in districts where the amount of summer heat and sunshine constitutes a limiting factor in production, it becomes a costly operation. There are other districts, however, of low rainfall and of long and hot summers, where the limiting factor, so far as climate is concerned, is not heat but moisture. In such cases the soil may be able to store up most of the rain that falls during the period of the fallow, and the partial sacrifice of one crop may be justified by the increase obtained in that which follows. Hence it is that in the south-eastern counties the

bastard fallow is often an economical method of weed control.

Bare fallows, too, may be introduced for other purposes than that of weed control. In dry-farming systems they are employed with the object of storing up a season's rainfall, on the principle of using two years' rain for one year's crop. Again, at the polar limits of arable cropping they become necessary because there is not time, within the limits of a single season, to prepare the land and also to grow a crop. Under our conditions bare fallows are useful in that they expose the soil to weathering agents and lead to improved tilth, but their chief object is that of cleaning the land. In general the bare fallow is to be regarded as a last resort in the struggle against weeds, to be used where other methods cannot be employed, that is to say on the heaviest clays, where neither roots nor potatoes can be planted with much chance of success. Ill-drained clays require the most frequent fallows both because they quickly become foul and because opportunities for spring and autumn cultivations are very limited.

The Maintenance of Soil Fertility.

Humus. — The importance of maintaining an adequate organic matter content in arable soils is well recognised. Under certain special sets of circumstances, for example on fen soils, or where plentiful supplies of organic manures such as seaweed or city refuse are available at low costs, the farmer may be free to grow such crops, and to dispose of them in such ways as will bring the greatest immediate returns. But under ordinary circumstances he must arrange that a greater or less proportion of the organic matter of his crops is returned to the soil as manure. The precise proportion that should be maintained between sales and home consumption, in order to secure in the long run the maximum net return, is very hard to determine. It depends, for one thing, on the physical characteristics of the soil. On deep, well-watered, alluvial lands like the Scottish carses or the Lincolnshire silts, considerable amounts of hay and

straw, as well as grain, etc., may be sold off year by year with very little ill result. On the other hand thin dry soils on chalk, and those of sandy or gravelly nature, as well as the stickier clays when occurring in dry districts, fall off greatly in cropping power if a large proportion of the produce be not returned to the land. It depends too on the staple crops of the farm. Wheat, owing to its deep-rooted habit and to its relative indifference, when autumn sown, to tilth, is much less dependent on the humus content of the soil than, say, oats, with their high moisture requirement and shallower root system.

The necessary supply of humus may be provided (1) by green manuring, (2) by the folding of animals on annual forage crops, (3) by laying the land away to temporary pasture, or (4) by the application of farmyard manure. In most actual cases two or more of these methods are used in conjunction. The crops grown for green manuring are normally catch crops, because the sacrifice of a full season's crop for this purpose can rarely be justified. Hence the conditions under which green manuring becomes a part of the system are those under which catch crops are likely to succeed, viz., light soil, fairly abundant rainfall, and mild winter climate. Even where catch crops succeed it will ordinarily be desirable to feed them off rather than to plough them in directly. The yield of catch crops is, however, uncertain, and their utilisation for feeding may involve large market transactions in live stock, in which case transport charges and sales commissions may be likely to amount to more than the crop is worth. In special cases the use of a full-season crop for green manure may be profitable. An interesting instance is to be seen in a system adopted in Germany on very light and rather acid sands. Here the choice of crops is so limited by the natural conditions that the provision of keep for stock becomes economically impossible; the rotation adopted is a three-course: lupins for green manure—potatoes—rye.

The grazing of temporary leys and the folding of annual forage crops are to be regarded as alternative methods of

serving the same ends—the provision of summer food for stock and the direct return to the soil of a large proportion of the organic matter produced. The one or the other forms a feature of all except the most intensive systems of arable farming. The cultivation of annual forage crops for summer folding involves more or less continuous cropping, and the main conditions which render this possible are a free-working and well-drained soil and a moderately high and evenly distributed rainfall. Under such conditions arable forage crops are more productive than grass, though the labour charges are necessarily much higher. On heavier soils, as well as where the growing season is shorter and the rainfall less evenly distributed, temporary grazing is usually preferable.

The folding of summer and winter forage crops, and the grazing of leys, tend to predominate in the less intensive arable systems, and where live stock occupies a position of primary importance in the farming scheme. These methods permit of the maintenance of fertility at a cost sufficiently small to be in keeping with the rather low gross income obtained from the land. On the most valuable arable soils, however, such methods interfere with the primary object in view, which is the production of marketable plant products. In such cases the live stock must be maintained chiefly on the by-products of the system, and house-feeding of stock, with the production of farmyard manure, becomes the chief means of keeping up the humus content. The handling and transport of large quantities of feeding stuffs and dung is a costly business, and can only pay when the gross income is kept at a high level.

Phosphates.—The problem of maintaining the chemical fertility of the soil is more or less bound up with that of the upkeep of the humus content, because all organic manures contain quantities of phosphates, potash, and nitrogen. As regards phosphatic manuring it is easy to lay down a general policy. Practically all systems of farming involve the removal of phosphates from the land, and it is the exception to find a soil that can be farmed successfully over a period of years

without recourse to phosphatic manures. These are relatively cheap; they do no harm when applied in quantities larger than are necessary; and unused surpluses are not lost by leaching, but remain available for future crops. Hence, in general, phosphates should never be allowed to become the factor limiting production, but should be applied up to the limit of their capacity to produce yield increments.

Potash.—With potash the position is somewhat more complicated. Where only live stock and their products are sold off the farm, the drain of potash is negligible; even when grain is sold as well the loss is comparatively small; but when potatoes, roots, or hay are sold in addition, the loss may become considerable. A good crop of potatoes, for example, removes as much potash as is contained in 2 cwt. per acre of the sulphate. Different soils, too, show very different potash requirements, heavy soils generally making little or no response to applications, while sandy and peaty soils often show very marked results. Again, it is possible to economise in the use of potash manures by various methods, *e.g.* by applying lime or sodium salts, or by growing especially deep-rooted species that reach down to subsoil reserves. For practical purposes potash may be considered as not liable to be washed out of the soil. While excessive doses of potash rarely do any particular harm, the cost per unit is normally two or three times as high as that of phosphate,[1] so that it must be used with more care. When all is said, however, the principle to be followed is the same as in the case of phosphates. It is generally most profitable to meet the demands of the plant in full, and it is safer to err in the direction of excess rather than in that of deficiency.

Nitrogen.—The most economical system in respect of the nitrogen supply is much more difficult to arrive at. Nitrogen, when it is purchased in the form of artificial manures, is costly; in the soil it is subject to serious losses through denitrification and leaching, and these losses become proportionately greater as the supply to the soil is

[1] Calculating in terms of K_2O and $Ca_3(PO_4)_2$ respectively.

increased; and, as regards a majority of arable crops, it is liable to cause direct harm when used in excess.

Economy in regard to nitrogen is therefore a matter that must be kept prominently in mind when systems of farming are being devised. Briefly the policy must aim at minimising the inevitable losses, at ensuring adequate, but no more than adequate supplies, in available form, to each successive crop, and at securing the necessary supplies by the most economical methods.

The chief losses of nitrogen occur during the storage of farmyard manure and through the leaching of nitrate from the soil. As regards the losses from dung, these fall most heavily on the portion derived from the urine, and thus from the digestible nitrogenous compounds in the food. Consequently, unless there are exceptional facilities for storing farmyard manure, the use of large quantities of albuminous concentrates in feeding is likely to form a very wasteful method of supplying nitrogen to the soil. As regards the handling of the dung, the loss is to some extent proportional to the length of the storage period, and it is greatest when this storage period extends over the summer season. Therefore, in so far as is compatible with other considerations, dung should be applied to the land as soon as possible after it is made. The other considerations involved are the seasonal distribution of labour and the sometimes undesirable effect produced by fresh dung on the physical condition of the soil. Apart from this, the method of storage is important; the material should be protected from rain and well compacted to exclude air; hence the advantage of covered courts over open courts or stalls, especially where intensive feeding is carried on.

The chief means of preventing loss by leaching is to ensure the presence in the soil, whenever it contains available nitrogen, of living plant roots. The loss of course falls principally on the nitrates produced in autumn, and this autumn production is highest in land that has recently been dunged. Therefore it is a principle of some importance in the arrangement of the rotation, that crops which receive

farmyard manure should be followed by autumn sown corn or by catch crops.

As regards the distribution of the nitrogen over the rotation, the main supplies are provided by the application of farmyard manure, by the consumption of crops on the land (particularly clovers and other legumes) with frequently cake fed in conjunction, and from the roots of leguminous crops. Nitrogen supplied in such forms has ordinarily a considerable effect in the second season, and a small but still appreciable effect in the third. Hence in the longer rotations, in which there are ordinarily two or more additions of organic nitrogen, these additions should be made at as nearly as possible equal intervals. Let us take as an example the six-course rotation already quoted in connection with labour distribution, viz.: (1) Seeds hay (aftermath grazed with lambs, receiving cake); (2) oats; (3) potatoes; (4) wheat; (5) turnips and swedes; and (6) barley and seeds. If in this case half the root crop is to be fed off along with hay and cake by sheep, the whole of the available dung will probably be best applied to the potato crop. If, on the other hand, the whole of the root crop is to be carted for cattle feeding, the dung should be divided between potatoes and roots.

The third point refers to the choice of means by which the nitrogen requirements of the farm as a whole are to be met. There are three main sources—the cultivation of leguminous crops, the purchase of nitrogenous feeding stuffs, and the purchase of artificial manures. Obviously the first of these sources is intrinsically the cheapest; but on the other hand we have the fact that the principal market crops of this country are non-leguminous. Thus under intensive arable conditions, where the chief object of the system is the production of marketable plant products, and where live stock fills a subsidiary role, the method is not very largely applicable. Even on grassland it is certain that a much higher level of production can be maintained with direct applications of nitrogen than by the utilisation of clovers, etc., as nitrogen collectors. Moreover, legumes, when grown

on rich soils, fix less nitrogen than when grown on poor. Under less intensive conditions, *e.g.* on the poorer sort of meat producing farms, the cultivation of legumes should generally be regarded as the most important method of nitrogen supply, because the gross income from the land will not justify the expenditure of large sums in the purchase of nitrogen. The use of wild white clover in systems of alternate husbandry is a striking example of the application of this principle. Many farmers, since they commenced to cultivate this species, have been able to make enormous reductions in their outlays for nitrogenous feeding stuffs and manures.

The use of purchased nitrogenous feeding stuffs, at the prices which ordinarily rule, and considered as a method of enriching the land, is wasteful and inefficient. The object to be kept in view in the purchase of cake should be that of meeting the protein requirements of the animal and not the nitrogen requirements of the soil.

Artificial nitrogenous manures, on account of their readily available form, may often be usefully employed even when an ample supply of organic nitrogen is secured by the above methods. Thus small dressings are often necessary in early spring in order to tide the plant over the short period between commencement of crop growth and that of active nitrification. They are further profitably applied to crops such as mangels and cabbages, where the nitrogen appetite is exceptionally large, and where the yield is highly elastic.

Lime.—The maintenance of soil fertility also involves the control of soil acidity, which is generally best accomplished by means of fairly frequent and moderately small dressings of lime. Heavy dressings at longer intervals involve the sinking of additional capital, usually without any compensating advantage. Considerable economies in lime may be effected by the continuous use of basic and neutral compounds of calcium, *e.g.* cyanamide or nitrate of lime in preference to ammonium salts, and slag, steamed bone flour, mineral phosphates, etc., in preference to superphosphates.

It may happen, where soils are very sour, showing lime requirements, running into many tons per acre, that the

cost of applying the quantities theoretically required will be prohibitive. This is particularly likely where other factors such as climate set a somewhat low limit to the productivity of the land. In such cases the only economically possible course may be to restrict cultivation to those species, such as oats, potatoes, rye and certain grasses, that show a high degree of tolerance to sour conditions, and to abandon the attempt to cultivate barley, wheat, mangels, etc.

Plant and Animal Hygiene.—The control of diseases and pests, both of crops and of live stock, is one of the constant concerns of the farmer and must receive due consideration in relation to the general farming scheme. When the natural mixed herbage of the ground is replaced, say, by a crop of swedes, or when the natural animal population is replaced by a flock of sheep, the farmer is disturbing the balance of nature and is giving to the enemies of these particular species an opportunity such as they never enjoy under natural conditions, to increase and multiply. Sometimes the consequences are not serious; thus healthy crops of mangolds and sugar beet can, with reasonable care, be produced year after year on the same land; and pastures may be stocked entirely, season after season, with fattening cattle, without any particular ill consequences to the animals.

Even when pests are potentially very harmful it may be cheapest and best to deal with them directly. Thus no farmer would think of modifying his general system of farming because of bunt attacking his wheat or scab his sheep; in both cases there is a cheap and satisfactory method of control. In other cases direct measures are only partially successful. For example, liming is useful against finger-and-toe in turnips, but it may be necessary, in order to keep the disease completely suppressed, to grow susceptible crops only at long intervals. Similarly husk in young cattle may be treated directly with some measure of success, but it is better, where possible, to avoid infection by arranging to have aftermaths or catch crops for autumn grazing. If these cannot be economically produced it may be best to house the animals and give up grazing altogether. Lastly

there are cases where no direct method of control can be economically applied, and where attack can be escaped only by introducing more or less fundamental changes in the farming scheme. Thus in some districts the farmer dare not risk more than a small area of turnips and swedes, on account of the ravages of flea beetle; in others he is obliged to grow only winter sorts of oats, because of the certainty of more or less severe damage of spring varieties by frit-fly; and in still others he may have to restrict the size of his flock because his land becomes "sheep sick."[1] In general there is least trouble with crop pests when a long rotation is adopted, and least with animal pests when a mixed stock is kept and when the animals can be given rather frequent changes of pasture.

There are, of course, other considerations to be kept in view when the system of farming is being devised. The capital and the credit facilities available to the farmer must be thought of, although ordinarily these should govern the choice of a farm rather than the choice of a system. So, too, the farmer must work out his scheme with reference to his own experience and skill in the several departments, and also with regard to the skill and experience of his employees.

II.—Examples of British Farming Systems.

The following descriptive accounts of farms are given as illustrations of the principles set forth above. In some cases the particulars are those of actual farms, typical of fairly wide areas; in others they are based upon the results of agricultural surveys and apply to the hypothetical average farm of the area in question. The financial data are based on an index figure for agricultural produce of approximately 40 per cent. above 1911-13 prices, and a wage level about 75 per cent. above that of the same period. Reference to the index figures published by the Ministry of Agriculture will enable the reader to revise the figures to conform with current prices.

[1] The condition is not understood. It implies that sheep no longer thrive on the ground. Possibly the trouble is partly nutritional and partly due to the accumulation of parasitic worms, etc.

I.—Welsh Mountain Sheep Farm.[1]

Natural Conditions—

The typical farm includes both mountain and valley land, with about half the total area lying above the 1000-foot level. The geological formations are Cambrian, Ordovician, and Silurian. Rainfall varies greatly with elevation and aspect, but is commonly of the order of 100 inches per annum. The mean annual temperature in the lowlands is high with a mild winter, but on the upper mountain slopes snow lies for long periods. The soil on the steeper slopes is thin, stony, and heavily leached. Despite the high rainfall these slopes suffer from drought, and the herbage consists entirely of drought-resistant species. Accumulations of peat occur in any flat or inadequately drained areas. The typical soil of the flatter lowland areas is a silty loam.

Economic Situation—

Apart from agriculture, stone and slate quarrying is the only industry of importance, and the district is thinly populated. Road and railway systems are not highly developed.

Allocation of Land and Stocking—

The farm is divided into three zones. There are a few small enclosed fields on the bottom near the homestead; the intermediate area of pasture, known as the Ffridd, is in a ring fence, while the upper mountain area is unenclosed. Legally the unenclosed mountain is not divided, each farm having the right of common grazing for a certain number of sheep, the number being apportioned to the amount of enclosed land. In practice, however, boundaries are generally recognised and the sheep of each farm are trained to keep their own ground. The whole flock is grazed on the open mountain during summer. At mating time and again at lambing the ewes are kept on the enclosed mountain pasture, while in winter they have the run of both the open mountain and the Ffridd. The low fields are used for hay with a few acres of roots and oats; some hay is also cut on the Ffridd. The ewe tegs are sent away to lowland farms, generally in the coastal areas or in Anglesey, for wintering. Apart from Welsh mountain sheep, normally uncrossed, the only stock consists of a small herd of cattle and occasionally a few mountain ponies.

Tenure and Rental—

Tenancies are generally from year to year. Most rents are between 1s. 6d. and 2s. 6d. per acre.

Labour—

The staff of the typical farm, carrying five or six hundred ewes, consists of the farmer, one shepherd, and one general labourer. Casual labour is employed for hay-making and occasionally at lambing time.

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[1] The authors are indebted to Mr F. Lloyd Bywater for permission to use material from an unpublished survey.

Capital—

The following figures apply to the average farm of 1300 acres, the valuation being made in autumn after the sale of lambs and draft ewes.[1]

Sheep—		
550 breeding ewes and gimmers at 30s.	£825	
200 ewe lambs at 20s.	200	
11 rams at £3	33	
		£1058
Horses—		
2 light carters at £25		50
Cattle—		
8 three- and four-year-old heifers in calf at £22	£176	
4 eighteen months old heifers at £15	60	
4 heifer calves at £7	28	
1 bull	30	
		294
Implements—		
2 carts, 2 sets harness, hay rake, etc.		140
Standing capital		£1542
Floating Capital—One year's expenditure as below		500
Total capital		£2042

Annual Expenditure—

Rent and rates—1300 acres at 2s.		£130
Wintering—200 ewe tegs at 10s.		100
Wages—1 shepherd	£104	
1 labourer	80	
Casual labour	30	
		214
Manures and feeding stuffs		30
Repairs to harness and implements		16
Sheep dip and miscellaneous		10
		£500

Annual Income—

180 draft ewes at 30s.	£270
220 wether lambs and 20 cull ewe lambs at 20s.	240
1800 lb. wool at 10d. per lb.	75
4 cows and calves at £25	100
	£685

[1] Ewes are drafted out at 4½ years old, having borne lambs for three years.

II.—East of Scotland Arable.

The system illustrated below is that normally followed in the more fertile lowland areas of Forfarshire, Fife, and Perth. The seven-course rotation, as given, is the commonest, but on the choicest and most highly-rented land a six-course, with the ley shortened to one year, is found, whereas on rather poorer land the ley lies three years.

Natural and Economic Conditions—

The altitude is from 150 to 250 feet, the land lying on a moderate slope with a southerly aspect. The mean annual rainfall is 27 inches. The winter climate is closely similar to that of the English Midlands, but the growing season is considerably shorter and the mid-summer mean temperature about four or five degrees lower. The geological formation is Old Red Sandstone, the soil a variable but generally rather free-working loam of good depth and rather stony. It becomes sour if drainage and liming are neglected. The area is well served with roads and railways and there is sea communication with Hull, London, etc. There is a considerable local market, but the area exports agricultural produce, particularly fat cattle and potatoes, to Glasgow, London, etc. It also supplies seed potatoes to English growers.

Allocation of Land –

The total area is 300 acres, 280 being arable and 20 permanent pasture. The rotation is: (1) oats, (2) potatoes, (3) wheat, (4) roots, (5) oats or barley, (6) seeds (about half hay, half pasture) and (7) pasture. On the whole this rotation is closely adhered to; a small area of sugar beet may be grown in place of roots and one cereal may partially replace another; or again if the twice-grazed lea is expected to be too rich for corn, potatoes may be substituted.

The normal scheme of manuring is as follows:—

	Dung.	Artificials, cwt.					
	Tons.	Lime.	Sulphate of Ammonia.	Super-phosphate.	Basic Slag, Bone Meal, etc.	Sulphate of Potash.	30 per cent. Potash Salts.
Oats	...	...	...	...	...	...	...
Potatoes	15	...	2	4	...	1½	...
Wheat	...	...	1	...	...	...	...
Turnips and Swedes	5[1]	10[2]	1	2	2	...	1½
Barley[3]	...	...	1	2	...	...	1
Seeds Hay	...	...	1	2	...	...	...
Pasture	...	...	...	...	...	...	...

[1] Actually about half the root crop receives 10 tons dung per acre with 4 cwt. artificial; the remainder 8 cwt. artificial only.
[2] Lime is actually applied in larger quantities at longer intervals.
[3] Barley after dunged or folded roots receives no manure.

Average yields are:—Oats, 7 quarters (21 cwt.); wheat, 4½ quarters (20 cwt.); barley, 5 quarters (20 cwt.); potatoes, 8 tons; turnips and

swedes, 20 tons; hay, 2 tons. Wheat, barley, and potatoes are all sold, except what is required for seed, also oats not required for horse feeding. All straw, hay, and roots are consumed on the farm.

Live Stock—

The permanent live stock consists of 11 work horses and 3 cows; about 80 head of cattle are fattened in winter and about 30 in summer. A flying flock of 60 draft ewes, for fat lamb production, is kept, and about 100 hoggs are fattened on aftermath and roots. Winter cattle consume about 6 lb. cake per day; summer fattening cattle an average of 4 lb. Ewes up to 2 lb.; lambs and tegs 1 lb. per day.

Capital—

The following is a summarised capital statement, based on a valuation made in August, before the commencement of harvest.

Standing Capital—		
11 work horses at £30	£330	
Field implements[1]	350	
Oil engine, thresher, and barn machinery[1]	400	
		£1080
Crop—		
40 acres wheat at £9	£360	
60 „ oats at £9	540	
20 „ barley at £8	160	
40 „ potatoes at £20	800	
40 „ roots at £12	480	
40 tons hay at £3	120	
		2460
Live Stock—		
3 dairy cows at £30	£90	
30 fattening cattle at £25	750	
100 store lambs at 40s.	200	
		1040
Miscellaneous—		
Straw, feeding stuffs, unexhausted manurial values, etc.		500
Total Capital		£5080
(Equivalent to nearly £17 per acre.)		

Annual Expenditure—

Rent, rates, and insurances		£650
Labour, 10 full-time men at £85[2]	£850	
Casual	120	
		970
Artificial manures		250
Feeding stuffs (45-50 tons)		450
Grass and root seeds		70
Miscellaneous—depreciation on horses and equipment, repairs, shoeing, veterinary charges, carriage and miscellaneous		220
		£2610

[1] At half new prices.

[2] Excluding value of perquisites produced on the farm.

Annual Income—

Crops (net yields, allowing for seed requirements)—

160 quarters (720 cwt.) wheat at 45s. per quarter	£360	
90 „ (360 „) barley at 40s. „	180	
220[1] „ (660 „) oats at 27s. „	say 300	
125 tons seed potatoes at £5 per ton	625	
125 tons ware potatoes at £3 per ton	375	
		£1840

Live Stock[2]—

80 winter fattened cattle at £9 per head	£720	
30 summer fattened cattle at £5 per head	150	
100 tegs at 24s. per head	120	
60 ewes with lambs at £3, 10s. per head	210	
420 lb. wool at 1s. 3d. per lb.	26	
		1226
		£3066

III.—Semi-Arable Sheep Farm, Scottish Border Area.

Natural Conditions—

The configuration is hilly, with moderate slopes, the farm lying between 300 and 700 feet elevation. The underlying rocks are chiefly sandstones belonging to the Carboniferous Limestone series. There is a good deal of glacial drift. The soil is a variable, but, on the whole, a medium loam. Annual rainfall 32 inches.

Economic Situation—

The area is almost purely agricultural. The main agricultural exports are fat and store sheep and cattle, and these find markets partly in the Lothians and Midlands of Scotland, partly in the Newcastle area and Yorkshire. Store sheep and draft ewes are sent in large numbers to the English Midlands.

Allocation of Land—

The total area is 800 acres. About 100 acres is good permanent grass, on which cattle fatten with little cake. Two hundred acres is good arable which in times of satisfactory cereal prices is farmed on a five-course rotation of (1) oats, (2) turnips and swedes, (3) barley, (4) and (5) seeds. Three hundred acres is moderate arable at a higher level farmed on a long-ley rotation of (1) oats, (2) turnips and swedes, (3) oats or barley, and a four to six years' ley including wild white clover. The remaining 200 acres is poorish upland pasture. The whole system is very elastic, and the area of pasture broken up annually varies according to the outlook for corn and stock.[3] At present (1928) the annual "break" is about 50 acres, giving

[1] Allowing for requirements of horses.

[2] "Gross profits" or differences between buying and selling prices.

[3] Between 1919 and 1926 the area of cereals and roots in Northumberland declined by 40 per cent. In Norfolk the decline was little more than 10 per cent.

100 acres cereals and 50 acres roots. About 80 acres is cut for hay. The overall rental is 20s. per acre, the best land being worth 40s. and the poorest about 8s. per acre.

Labour—

The staff consist of a working bailiff, three ploughmen, one full time shepherd, and one shepherd-labourer, one cattleman, one general labourer, and two women workers—a total of eight men and two women. Casual labour is required for root thinning.

Manuring—

The use of nitrogenous artificials is exceptional. Roots on the lower and better land receive all the available dung together with 4 or 5 cwt. per acre of phosphatic manure. Roots on the poorer outlying fields, which are grown for folding, get 5 to 6 cwt. slag, or its equivalent, with 2 cwt. potash salts. Ten to 15 cwt. ground lime is applied if necessary. Grassland that has been down for five years and is intended to be longer gets 5 cwt. basic slag or ground mineral phosphate.

Stocking—

The farm is worked with seven horses and one tractor. It carries a breeding flock of half-bred (Border Leicester × Cheviot) ewes which are drafted at 3 crop (4½ years) and replaced by purchased ewe lambs. The ewes are bred to Suffolk and Oxford Down rams, and of the lambs about one-third are fattened and two-thirds sold as stores. The breeding cattle comprise 20 Galloway cows rearing Shorthorn cross (blue-grey) calves, which are sold fat at two years old. About 100 two-year-old store cattle are bought annually, chiefly in November. These are wintered as stores, the best being sold fat off the grass from June to August and the remainder finished in yards by December or January.

Capital—

The following capital statement is based upon a valuation in May, which is the usual time of entry.

Capital—

Standing Capital—

7 work horses at £30	£210	
Tractor and field implements	500	
Thresher, barn machinery, sheep dipper, and miscellaneous	500	
		£1210

Live Stock—

450 ewes with 675 lambs at £6 per couple	£2700	
160 ewe hoggs at £3, 10s.	560	
7 rams at £10	70	
20 Galloway cows and calves at £24	480	
1 bull	30	
20 blue-grey yearlings at £15	300	
100 fattening cattle at £22	2200	
		6340
Carry forward		£7550

Brought forward		£7550
Crops and Tillages—		
100 acres cereals at £7	£700	
50 „ roots (seed and tillage) at £5	250	
50 „ grass seeds at £2	100	
	——	1050
Miscellaneous—		
Feeding stuffs, manurial residues, etc.		400
		£9000

(Equivalent to over £11 per acre.)

Annual Expenditure—

Rent, rates, insurances		£920
Manures		160
Feeding stuffs (50 tons)		450
Grass and root seeds		120
Labour—8 men at £80[1]	£640	
2 women at £55	110	
Casual	40	
	——	790
Live Stock—		
160 ewe lambs at 45s.	£360	
Rams and bull	40	
Depreciation on breeding cows	30	
100 store cattle at £18	1800	
	——	2230
Miscellaneous—		
Depreciation on horses and implements, repairs, shoeing, veterinary charges, sheep dip, carriage, etc.		300
		£4970

Annual Income—

Crop—		
100 quarters (400 cwt.) barley at £2 per quarter		£200
Live Stock—		
150 draft and cull ewes at £3	£450	
675 lambs and tegs at 45s.	1518	
18 home-bred two-year-old cattle at £25	450	
100 fat cattle at £27	2700	
Wool, 4400 lb. at 1s. 3d. per lb.	275	
	——	5393
		£5593

[1] In addition to cash wages there are free cottages and various perquisites.

IV.—Midland Grazing Farm.[1]

The Market Harborough district, in which the farm described below is situated, is one of the best known fattening pasture districts in England. The system exemplified is not the only one followed in the area, there being a considerable number of dairy holdings and some mixed farms.

Natural Conditions—

The farm is situated in the Welland valley at an elevation of 200 to 350 feet. The configuration is gently undulating and the farm is well watered. Rainfall is 30 inches per annum. The geological formation is chiefly Lias Clay with a very little alluvium and some mixed oolite and lias in the higher areas. The lias soil is a very rich and retentive clay loam of great depth and carrying very rich pasture. The other land carries very good grass of a less "strong" character. The herbage consists largely of perennial ryegrass, cocksfoot, and timothy, with variable amounts of foxtail, crested dogstail, red fescue, and rough stalked meadow grass. Clovers (wild white and sometimes wild red) are present but not very abundantly. The chief weed is buttercup.

Economic Situation—

The district is admirably served with roads and railways. There is little local industry, but Northampton, Leicester, etc., are within easy reach.

Allocation of Land—

The whole area is 300 acres, all grass. Of this about 150 acres is typical "strong" feeding land which will "fatten a three-year-old bullock and a sheep per acre in the season"; 100 acres is good enough to fatten heifers and cows, and 50 acres is of relatively inferior quality and is used for store cattle and sheep. About 40 acres of the poorer grass is cut for hay, after having been grazed until the end of May.

Live Stock—

There are three cart horses, normally pedigree Shire mares used for breeding. Horse breeding is, however, discontinued under present conditions. In May and June when the stock of cattle is at its maximum there are about 240 head, of which 150 are fattening steers of 9 to 10 cwt. (store weight), 60 heifers and barren cows, and 30 two-year-old stores. About one-third of this stock is carried over winter, with the help of a certain amount of grass-and-hay keep hired from farmers in surrounding districts. The remaining cattle are purchased in spring. Sales of fat cattle begin in the end of June and continue till November with the peak about October. There is a flock of 80 breeding ewes, Kerry Hill, Half-bred or Masham, which are mated to Oxford, Suffolk, or Ryeland rams. Most of the ewes bought are drafts from breeding flocks, and are kept for two years. About half the lambs are sold fat in summer, the remainder being wintered on the grass and fattened the following summer. In addition about 100 lambs are bought in autumn to be wintered and summer fattened. The average head of stock carried throughout the year is 150 cattle and 260 sheep.

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[1] The authors are indebted to Mr J. Llefelys Davies for permission to embody information from his *Economic Survey of a Grazing District in the Welland Valley.*

Labour—

There are three regular hands, all skilled stockmen. A little casual labour is required for hay-making.

Rent, etc.

The overall rental is 45s. per acre. Some of the choicest fields are worth about £4 and the store pasture about 20s.

Capital—

[The following statement refers to the period May to June when the stocking reaches its highest point. Since the investment at other seasons is substantially lower it is the custom to finance some of the spring purchases by means of temporary loans.]

Standing Capital—		
Horses, 3 at £30	£90	
Equipment—carts, harness, hay-making, machinery, etc.	200	
		£290
Live Stock—		
150 three-year-old steers at £22	£3300	
60 heifers and barren cows at £18	1080	
30 two-year-old store cattle at £16	480	
80 ewes and lambs at £5, 10s. per couple	440	
100 tegs at £3	300	
		5600
Miscellaneous—		
Feeding stuffs, hay, unexhausted manurial values, etc.		200
		£6090
Less temporary loan		1500
Balance, capital		£4590
(Equivalent to £15 per acre.)		

Annual Expenditure—

Rent, rates, and insurances	£750
Labour, including casual labour	300
Manures	60
Feeding stuffs, including winter keep	300
Depreciation on ewes	40
Interest charges	30
	£1480

Annual Income—

Gross Profits[1] *on*—	
80 feeding cattle (bought in autumn) at £9 per head	£720
120 feeding cattle (bought in spring) at £5 per head	600
40 stores (bought in spring) at £3 per head	120
100 tegs at 25s.	125
110 home bred lambs and tegs at 50s.	275
Wool, 480 lb. at 1s. 3d. per lb.	30
	£1870

[1] Difference between buying and selling price.

V.—Cheshire Dairy Farm.

Natural Conditions—

The country is low-lying (150 to 200 feet), rather flat and well sheltered. The annual rainfall is 30 inches. The grazing season is long and the winter fairly mild. The geological formation is KEUPER MARL, with more or less boulder clay, giving rise to a rich retentive clay soil.

Economic Situation—

The farm is situated in the southern end of the county, where the industrial population is not very large. The great industrial areas of South Lancashire on the one hand, and the Potteries on the other, are about thirty miles distant. Some milk is sent to these areas, but the market for liquid milk is not nearly large enough to absorb the available supplies. Cheese making is therefore largely resorted to. Road and railway communications are good.

Allocation of Land—

The farm extends to 200 acres. Of this some 60 acres is relatively light, and is arable. The remainder is permanent grass, 120 acres pasture and 30 acres meadow. The rotation is six-course, viz. (1) oats, (2) mangels, swedes, cabbage, etc., (3) wheat or oats, (4), (5) and (6) seeds, generally mown two years and grazed the third.

Manuring—

The permanent pasture receives the equivalent of 5 cwt. per acre of high grade slag every fifth year. Steamed bone flour or ground mineral phosphate may be used in preference to slag, according to current prices. The meadows have 10 tons dung every third or fourth year, with 3 cwt. superphosphate and 1 cwt. sulphate of ammonia in intervening years. Root land is dressed with 10 to 18 tons dung and with 4 to 6 cwt. of appropriate artificials. Cereals get no direct manuring. Some liming is done at irregular intervals.

Yields—

Meadow hay averages 2 tons per acre and seeds hay over 50 cwt.; oats, 7 quarters (21 cwt.); wheat, 5½ quarters (24 cwt.); mangels, 30 tons; cabbage, kale, etc., 25 tons; swedes, 20 tons.

Live Stock—

The dairy herd consists of about 80 cows, with about 50 head of young stock. There is normally a flying flock of 40 ewes, producing fat lambs. Eight to ten breeding sows are kept, giving a total of 80 or 90 pigs, which are sold as rather large bacon at eight months old. Most of the cows calve in spring; the summer milk is made into cheese and the whey fed to pigs. Liquid milk is marketed in winter.

Labour—

There are seven full time hired men; one or two casual labourers are employed from June till August. In addition to the farmer himself, one member of the family is fully employed from April till October as cheese-maker; one other is partly employed in milking.

Capital—

The following would represent the capital investment as at Lady Day (25th March).

Horses—		
4 at £30		£120
Equipment—		
Field and barn implements	£180	
Dairy equipment	200	
	——	380
Cattle—		
80 dairy cows at £25	£2000	
10 heifer calves at £4	40	
17 yearling heifers at £12	208	
17 2-year-old heifers at £18	306	
2 bulls at £40	80	
	——	2634
Sheep—		
40 ewes and lambs at £4, 10s.		180
Pigs—		
9 sows, 1 boar at £8	£80	
80 other pigs at £3	240	
	——	320
Poultry and Poultry Equipment—		
(400 head)		300
Crops, tillages, hay, straw, roots, feeding stuffs, and residual values		500
		£4434

(Equivalent to £22 per acre.)

Annual Expenditure—

Rent (50s. per acre)		£500
Rates, insurance		90
Labour, including family labour		850
Feeding stuffs—110 tons at £10		1100
Seeds		20
Manures and lime		90
Cattle—Annual charge of bulls	£20	
Purchase of cows—4 at £30	120	
	——	140
Sheep—40 ewes at £3		120
Miscellaneous—veterinary charges, repairs, depreciation, shoeing, marketing, miscellaneous stores, etc.		200
		£3110

Annual Income—

360 cwt. cheese at 80s. per cwt.	£1440
8000 gallons winter milk at 1s. 2d. per gallon net	465
50 calves at £2	100
120 fat pigs at £6	720
40 ewes with lambs at £5, 10s.	220
Wool	16
Cast cows, 16 at £12	192
Poultry and eggs	400
Wheat, 20 quarters at 45s.	45
	£3598

VI.—Suburban Arable Farm.

Natural Conditions—

The elevation is 150 feet, and the configuration flat. The geological formations are Cretaceous and Oligocene with superficial deposits of gravel and brick earth, giving rise to useful loam soils. Annual rainfall is 25 inches.

Economic Situation—

The farm is within 20 miles of London, and has a railway siding upon it. Road communications are good.

Allocation of Land—

The total area is 500 acres, 450 being arable and 50 permanent grass. Apart from a few acres of horse paddocks the latter is used as meadow. The rotation is four-course, viz. (1) Wheat or winter oats, with white or alsike clover as a catch crop, (2) potatoes, (3) wheat, and (4) seeds hay (once cut followed by a bastard fallow).

Manuring—

The catch crop is ploughed in as green manure, along with 18 tons per acre of London stable manure. In addition the potatoes receive 7 cwt. mixed artificials. The cereals have a top dressing of 1 cwt. nitrogenous manure in spring if necessary. Ten cwt. ground lime per acre is applied at rather long intervals.

Labour—

There are 20 regular hands. A gang of 40 to 50 casual workers is employed for two or three weeks on potato lifting.

Live Stock—

The farm is worked with 14 horses and one tractor. Pigs are sometimes purchased to consume small potatoes and tail corn, but these may be sold. There is no other live stock.

Rental—

The rent is 45s. per acre.

Capital—

The following capital statement applies to Michaelmas (29th September), assuming that none of the current year's crop has been marketed :—

Horses—		
14 at £30		£420
Equipment—		
Field implements	£600	
Tractor, oil engine, thresher, trusser, etc.	700	
		1300
Crop—		
150 acres wheat (in stock) at £12	£1800	
750 acres oats (in stock) at £10	750	
150 acres hay (in stock) at £7	1050	
112 acres potatoes at £20	2240	
		5840
Miscellaneous—		
Dung, unexhausted manurial values, tillages, etc.		1100
		£8660

(Over £17 per acre.)

Annual Expenditure—

Rent, rates, insurance		£1350
Labour, including casual labour		2100
Manures, including dung		1100
Seeds—Potato seed	£650	
Grass seeds	140	
		790
Miscellaneous—		
Repairs, depreciation, shoeing, oil and materials, carriage, etc.		600
		£5940

Annual Income—

Wheat, 700 quarters (3150 cwt.) at 45s.	£1575
Oats, 250 quarters (750 cwt.) at 28s.	350
Hay, 250 tons at £4	1000
Straw, 300 tons at £2	600
Potatoes, 800 tons (including small) at £4	3200
	£6725

III.—Modifications of the System in relation to Changing Conditions.

The economic situation of a farm is, of course, liable to change; the migration of population, the improvement of transport facilities, and the discovery of new wants by mankind create new markets. Moreover, the organisation of the farm must keep abreast of progress in agricultural technique. For these reasons it is important so to organise that changes in the system may be carried out, as they become necessary, with a minimum of cost and inconvenience. It is not meant to imply that such changes, in so far as they relate to essential features of the system, are to be made lightly or often, because immediate loss is usually inevitable, and this can only be recovered through an increase of profits lasting for some considerable time. To change rotations, for example, involves often a redivision of the farm into fields, with perhaps the uprooting of hedges and the erection of new fences; and it necessitates a certain amount of miscropping, with consequent diminished production or increased costs. Again, to substitute sheep for cattle, or the grassland type of sheep and system of management for arable sheep and the folding system, will generally involve the scrapping of a certain amount of old and the purchase of new equipment. The possibility that changes may become desirable should, however, be kept in mind from the outset, and a system which will permit of easy modification is, other things being equal, preferable to one that does not possess this characteristic of elasticity. Thus, so far as is compatible with their immediate use, buildings should be so constructed as to be readily adaptable to different purposes; fields should be so laid out and so placed as to allow of their being thrown together or subdivided as cheaply as possible; and the rotation adopted should be such as will permit of considerable alterations in the proportions of different crops without a complete redistribution of the fields into new "shifts" or "breaks." One five-course rotation may be readily changed into another and very different five-course, but a change

from a four- to a five-course is almost necessarily much more costly and troublesome. In this connection it is to be noted that the longer rotations are much more readily adaptable than the shorter. Thus the existing British four-course systems show but few variations in essentials; generally speaking, half the land is under corn, a fourth under fallow crops, and the remaining fourth under "seeds" or forage crops. A six-shift is, on the other hand, principally by virtue of the possibility of varying the length of duration of the temporary ley which it includes, highly adaptable to varying conditions. The following table, showing some of the six-course rotations actually in use in the northern areas of England and in Scotland, illustrates this adaptability:—

Locality.	East Lothian.	East Lothian.	Cumberland, Aberdeen, etc.	Various.	Moray.	West of Scotland.	Northern.
Soil. . .	Good Medium.	Dunbar Red Soil.	Medium Soil.	Heavy Soil.	Loam.	Heavy.	Loam.
1	Oats	Potatoes	Oats	Oats	Oats	Silage	Potatoes
2	Potatoes	Roots	Roots	Beans	Oats	Oats	Oats
3	Wheat	Barley	Oats	Wheat	Roots	Seeds	Roots
4	Roots	Potatoes	Seeds	Roots or Fallow	Barley	Seeds	Barley
5	Barley	Oats	Seeds	Barley or Wheat	Seeds	Seeds	Seeds
6	Seeds	Seeds	Seeds	Seeds	Seeds	Seeds	Seeds

The degree of freedom in cropping and in the method of disposal of the produce—in other words, the frequency with which changes may be made in the system—is, of course, greatest under suburban conditions, where supplies of organic manures are available and where casual labour can be secured as and when required. Under such conditions the farmer grows from year to year what crops he chooses, and disposes of them in whatever manner appears to be likely to yield the greatest immediate profit. The only real restriction is that imposed by the necessity for occasional fallow crops. Under other circumstances, where the maintenance of fertility involves the keeping of live stock, where labour supplies are inelastic, and where the marketable commodities are restricted to such as will bear considerable transport costs, the farmer

must take a longer view, and must generally, when change is decided upon, work out the new system in all its details before he abandons the old, and endeavour to proceed by a clean cut from the one to the other.

Changing conditions react upon the farmer by influencing the prices, on the one hand, of his raw material, labour, etc., and on the other of the commodities which he has to sell. The general level of money prices is, of course, mainly dependent on the quantity of currency in circulation in relation to the requirements of the community; prices rise as the amount of currency increases, and fall as it is reduced. But commodity prices adjust themselves to such changes much more rapidly than wages or rents, with the consequence that during periods of rising prices the profits of the farmer tend to increase at the expense of the labourer and the landowner; while during periods of falling prices, the labourer and the landowner tend to gain in real income, while the farmer can ordinarily expect to lose. But quite apart from questions of currency, the relative values of service and of goods (real wages and real prices) may and often do change quite markedly within short periods of time. A familiar illustration is furnished by the last quarter of the nineteenth century. Comparing wages and prices for the two decennial periods centred at 1870 and 1890 respectively, the changes were as follows:—

Price Changes 1870-1890.

	Rise (per cent.)	Fall (per cent.)
Wheat	—	46
Barley	—	32
Oats	—	32
Cheese	—	21
Beef	—	20
Mutton	—	10
Wool	—	35
Wages of Agricultural Labourers	12	—

The chief causes and the chief effects of these price changes may be briefly summarised.

(1) There was a general fall in the price of agricultural produce. This was occasioned largely by causes connected with currency; the increase in the world's supply of gold was insufficient to balance the increase in world trade. Money became scarcer, in relation to exchangeable commodities, and therefore the general level of commodity prices fell. There was also a cheapening of transport, through the development of railways and shipping and the concurrent breaking up of virgin lands. These developments in large measure deprived the British farmer of his advantage of proximity to the largest markets, and he was forced to meet the new situation by adopting a less intensive system of farming, to seek a lower plane of production on which a balance between outlay and expenditure could be re-established. The fall in prices was also due, to some extent, to a general cheapening of production, the chief factors being the introduction of new machinery, such as the binder, and an increase in the supply and a decrease in the cost of artificial manures. In these latter respects the British farmer was of course at no disadvantage.

(2) There was a rise in agricultural wages, which accentuated the results of the fall in prices. This rise in labour costs was due largely to the competition of urban industries, which were in a prosperous condition, and in a lesser degree to emigration of labourers to the new countries.

(3) The fall in prices was by no means uniform in respect of different products. The larger areas that were being brought under cultivation were on the one hand specially adapted for wheat (*e.g.* North America), and on the other hand for wool (*e.g.* Australia). Moreover, the problem of cheap transport for meat and dairy products was neither so completely nor so rapidly solved as for grain and wool. Again, there was an increase in prosperity of the industrial population which, taken in conjunction with the fall in the price of bread, led to an enlarged demand for meat and dairy produce. Hence the fall in these commodities was relatively small, and their production became relatively profitable.

The following table, giving the changes in the acreage

of crops grown and in the numbers of live stock kept, as between 1880 and 1900, shows the results of the change in economic conditions. The live-stock figures do not fully reflect the increase in meat production, because they take no account of the earlier maturity of the animals at the later period; and again, the sheep figures are somewhat difficult of interpretation because in their case a dual production—of meat and wool—is involved. The oat figures, too, indicate some other influence than that of the market price of the grain, the fact being, of course, that most of this country's production of this cereal is used for stock feeding.

Labour, Acreage, and Live Stock Changes, 1880-1900.

	Increase (per cent.)	Decrease (per cent.)
Wheat	...	41
Barley	...	21
Oats	...	1
Cows in milk, etc.	10	...
Other cattle	20	...
Sheep	...	2
Persons engaged in agriculture	...	11

A further example of important changes in relative values is provided by a comparison of the prices and wage levels during the past few years with those ruling just before the European War. The changes are clearly indicated by the index figures published by the Ministry of Agriculture by which the price of each commodity is expressed as a percentage of its mean price during the period 1911-1913 (see p. 698). Certain of the commodities in the list, such as potatoes, pigs, and wool, have fluctuated so much in price that no general tendency can be traced. It may, however, be noted that oats, and still more hay, have been consistently cheap in relation to other commodities. This is probably accounted for by the increase of mechanical transport in cities, and the consequent decline in the market for horse fodder. Fat cattle, too, have been relatively cheap, owing to the increasing competition from overseas. Milk, on the other hand, has consistently maintained a relatively high level. However,

by far the most striking changes in the economic situation are the greatly enhanced wage level and the marked fall, in relation to the general index figure, in fertiliser prices. Clearly the main object of the farmer must be to carry out such reorganisation as will lead to an increase in output per man; and an increasing use of artificial fertilisers is indicated as the most economical method of maintaining the output per acre.

Percentage Increases over 1911-1913 *in the Prices of Agricultural Produce and Farm Requirements, and in Wages during the harvest years* 1923-1924 *to* 1926-1927.

	1923-4.	1924-5.	1925-6.	1926-7.
Farm Produce—				
Wheat	38	65	62	56
Barley	43	65	31	43
Oats	33	40	32	23
Fat Cattle	52	41	46	30
Fat Sheep	83	97	60	48
Bacon Pigs	33	52	81	61
Pork Pigs	43	54	83	65
Hay	4	1	5	4
Potatoes	135	137	38	77
Milk	70	71	70	62
Butter	60	69	58	43
Cheese	72	54	73	39
Poultry	74	66	59	42
Eggs	74	67	63	47
Wool	92	37	20	33
General Increase	60	62	53	47
Farm Requirements—				
Feeding Stuffs	45	60	28	31
Fertilisers	18	15	13	13
Wages of Agricultural Labourers	56	72	75	75

The third main cause of price changes is the year-to-year variation, due to weather influences, in the quality and yield of particular products. In earlier times this was infinitely the most important cause, each small community being dependent on the harvest of its own area; but with modern transport facilities and world markets its influence has become relatively small. It is true, indeed, that the world's

crop of, say, wheat or wool is not absolutely constant, yet the effects of weather in different countries and continents do in fact cancel out to a large extent. The only prices that are liable to be greatly affected by seasonal influences are those, on the one hand, of commodities that are difficult of transport, such as vegetables or milk, and on the other hand of such as are produced, as regards a large proportion of the world's supplies, in areas liable to the same climatic variations. Thus the dependence on the southern United States for a very large proportion of the world's crop of cotton has tended in the past to instability in the price of this commodity.

It is of some importance that the farmer should try to form clear judgments regarding the causes of particular price and wage movements, because farming policy must be based on probable future prices rather than on those of the moment. Obviously if we take a commodity like potatoes, of which a surplus from one year cannot be carried over to the next, a bountiful harvest will produce a great fall in price, and the crop may in consequence become exceedingly unprofitable for the season in question. But such an occurrence must not be allowed to influence future policy, which can only be safely founded on the expectation of average seasons. With commodities such as wheat and wool, which can be stored without great cost or risk of loss, the effect of annual fluctuations in yield tends to be less in amount but more lasting—*e.g.* a small world's crop of wheat tends to raise the price to a moderate extent over a period of perhaps two or three years. Some account should therefore be taken, in framing future policy, of existing stocks of such commodities.

As regards currency changes, the profitable policy would doubtless be, in periods of inflation, to force production to its utmost limits, to borrow capital, and to employ much labour; and conversely, in periods of deflation, or falling prices, to cut expenses, to reduce investment in the business and to place all possible reserves of capital in safe security. But in practice currency movements are nearly impossible of prediction.

When price movements are the results of fundamental economic changes, or of definite improvements in methods of production, farm policy must be changed boldly and at once, so as to be brought into harmony with the new conditions. A clay land farmer who foresaw, in the 'eighties, that a long-lasting period of low grain prices was inevitable, and who threw down his land to grass and turned from wheat to beef or milk, escaped from the succeeding period of depression comparatively unscathed ; whereas his neighbour struggling on with his old system of cultivation, was doomed to almost certain bankruptcy.

Changes in farm policy may take either of two forms. They may consist in replacing one crop by another, or one type of live-stock by a different type. In certain cases such replacements do not involve any fundamental change in the organisation, for example, when one autumn cereal is substituted for another, or when grazing sheep are replaced by grazing cattle. Other substitutions will obviously necessitate changes in equipment, or will involve modifications in the labour organisation, stocking, etc., so that a true judgment regarding the balance of advantage is often difficult to form.

Substitution of one line or department for another may be made necessary by changes either in the relative prices of commodities or in their relative costs of production. For example, an increase in local population may induce a change from butter-selling and calf-rearing to whole milk-selling; or a rise in wages, unaccompanied by any change in prices, will tend to produce a change from arable to grass.

Changed economic conditions may be met not only by the substitution of one product for another, but to some extent also by altering the general plane of our husbandry. It is true that potato-growing will ordinarily involve more labour and heavier manuring than grain production, and that milk-selling is almost necessarily a more intensive business than beef production. But any department and any system may be carried on with a greater or lesser degree of intensiveness. Expenditure in producing crops

is subject to the economists' "law of diminishing returns"—that is to say, increased application of labour or of capital beyond a certain point produces a steadily diminishing proportionate return. The result is that for any given price level there is some point at which our expenditure must halt if the maximum net profit is to be secured. This general law is illustrated by the following figures[1] relating to the yields of potatoes obtained on plots receiving varying quantities of farmyard manure:—

Plot.	Dung applied. Tons per Acre.	Potatoes Gross Yield. Tons per Acre.	Increase (tons), produced by each successive addition of 4 tons dung.
1	0	4·6	...
2	4	5·9	1·3
3	8	6·7	0·8
4	12	7·4	0·7
5	16	7·8	0·4
6	20	8·0	0·2

If we assume an arbitrary value of 8s. per ton for dung, it will be clear that the maximum profit is obtained by different applications, according to the price obtained for the crop. In the following table the values and the profits from the applications are worked out for prices of 30s., 60s., and 120s. per ton respectively.

Plot.	Cost of Dung at 8s. per Ton.	Gross Yield. Tons.	Gross Value of Crop at, per Ton,			Profit or Loss per Acre, from Manure at, per Ton of Crop,		
			30s.	60s.	120s.	30s.	60s.	120s.
1	...	4·6	138s.	276s.	552s.	...	...	..
2	32s.	5·9	177s.	354s.	708s.	+ 7s.	+46s.	+124s.
3	64s.	6·7	201s.	402s.	804s.	− 1s.	+62s.	+188s.
4	96s.	7·4	222s.	444s.	888s.	−12s.	+72s.	+240s.
5	128s.	7·8	234s.	468s.	936s.	−32s.	+64s.	+256s
6	160s.	8·0	240s.	480s.	960s.	−58s.	+44s.	+248s.

It will be clear that if the potatoes sold at only 30s. per ton, the most profitable application was 4 tons of farmyard manure, the others in fact showing a loss; if they sold at

[1] From Aereboe, *Landwirtschaftliche Betriebslehre.*

60s. the most profitable dressing was 12 tons per acre, and if at 120s., 16 tons per acre. A still higher price for the crop would have rendered the 20-ton dressing the most profitable.

The same law is illustrated by the following results obtained from varying quantities of a standard artificial applied to the potato crop in conjunction with a uniform dressing of 12 tons farmyard manure.[1] The cost of the artificial is taken at 8s. per cwt., and the value of the crop at £1, £2, and £4 per ton.

Artificial Applied per Acre.	Mean Yield per Acre.	Profit or Loss from Artificial at, per ton of Crop,		
Cwt.	Tons.	£1.	£2.	£4.
Nil.	9·25	...	...	...
4	11·64	+16s.	+64s.	+160s.
8	13·01	+11s.	+86s.	+236s.
12	14·09	− 1s.	+94s.	+383s.
16	11·02	−73s.	−17s.	+ 94s.

The limit of production in this case is reached at 12 cwt. per acre, a further dressing actually depressing the yield. At the very low price of £1 per ton for potatoes the most favourable result is produced by the use of 4 cwt. of artificial. At £2 per ton it is a matter of little consequence whether 8 cwt. or 12 cwt. is used, whereas at £4 per ton 12 cwt. per acre is by far the most profitable dressing. Of course under less favourable climatic and soil conditions the limit of profitable manuring would be lower.

Other expenses in production are subject to the same general rule; there is an optimum point in expenditure and any greater or less application of the particular element concerned will result in a diminished profit. When prices are relatively high, or when a particular raw material, or labour, is cheap, money will be lost if we attempt to cut expenses to too low a figure; on the other hand, "high farming is no remedy for low prices."

[1] Midland Agricultural College. The yields are the mean of 1922, 1924, and 1925 crops.

CHAPTER IV

COSTS OF PRODUCTION

It is well known that the determination of farming costs is beset with peculiar difficulties. At first sight it might seem a simple matter to allocate the whole expenditure of the farm to one or other of its departments, to deduce the cost of production of a gallon of milk, a hundredweight of wheat and so on, and finally, by a comparison of costs and ruling prices, to discover the profit or loss on each commodity. Just so the manufacturer distributes his costs of material, labour, etc., and his overhead charges, and arrives at the cost of production of any article that he makes.

In farming, however, the following rather special circumstances have to be considered:—

(1) Even with fixed wages, known costs of raw material and identical management, production costs vary within wide limits from year to year. What interests the farmer is not the cost of producing a given crop in a particular season, but the normal cost of producing the average crop.

(2) Many of the products of the farm are in a strict sense joint products, *e.g.* corn and straw, mutton and wool, milk and calves, beef and farmyard manure. When one of two such products is of relatively minor importance, the price secured or the value assumed will not greatly affect the cost of production of the other. But in certain cases—for example that of oats and oat straw—the allocation of costs is a matter of considerable importance and it is largely a matter of guesswork; moreover, no conventional system of allocation will be valid for all farms.

(3) In other cases, although two or more commodities may be separate products, they may form necessary com-

plements one of another. For instance, if we grow corn we must also, generally speaking, have fallow crops. It is true that we can adopt some conventional method of distributing the cost of the fallow over the rotation. But if, having done so, we find a loss on roots and a profit on corn, this may only indicate that the convention used was not appropriate to the case.

(4) Large book-transfers, as between one department and another, are inevitable. If a farmer produces hay for home consumption, at what price is he to charge it to his cattle? The usual answer is that the figure should represent the cost of production. But if the hay is partially or completely spoilt this procedure may lead to the showing of a fictitious loss on the cattle. The same problem arises in the common case of a partial or total failure of a root crop. On the other hand, if a good crop of hay or roots happens to be produced very cheaply, the stock may show a large unreal profit.

(5) In the usual practice of cost accounting, labour, except when it is actually paid at overtime or special rates, is charged for all operations at a flat rate per hour. Indeed any other system results in impossible complications. But it is clear that the value of the work performed varies between one operation and another—say as between hay-making, spreading manure, and mending sacks. It follows that with such a system a farmer's accounts may show that he can produce a certain quantity of good hay at a low cost. But if he attempts to increase his acreage either the cost will rise, owing to the employment of labour at special rates, or the quality will suffer because the crop is not dealt with in proper season.

(6) The processes of production in agriculture are slow. Costs may begin to be incurred many months or even several years before the final product reaches the market. Cost accounts may enable the farmer to see the relationships between past costs and current prices, but he is more interested in the probable relationships between current costs and future prices.

Other questions that are difficult to answer arise in con-

nection with the basis of valuation in the annual stocktaking; in connection with the distribution of overhead charges; in the valuation of manurial residues and so on. If broad principles are adopted, points of real practical interest may be obscured, whereas if the methods of the merchant or manufacturer are applied, large "paper" profits or losses may be shown.[1]

It is not intended to suggest that cost accounts are valueless, but only that they do not in themselves provide a complete answer to questions of farming policy. They must be interpreted with care, and with full knowledge of all the conditions under which the farm is being conducted.

The following examples, based on recent studies by agricultural economists, indicate the kind of information that cost accounts provide and the uses to which it can be put.

I.—The Cost of Grazing.[2]

Grazing costs on a large number of Yorkshire farms have been collected by Ruston and Critchley. The following is the average cost per acre for the whole of the farms dealt with during the two years 1924 and 1925.

	£	s	d
Rent	1	7	3
Rates	0	4	9
Seed	0	0	3
Manures and lime	0	8	2
Standing charges	0	1	7
Man labour	0	4	4
Horse labour	0	1	10
Total	2	8	2

It will be noted that other costs add about 50 per cent. to the total for rent and rates. This proportion was about 40 per cent. in 1914-1915, rose to over 100 per cent. in 1919, and has since fallen.

[1] For an explanation of cost accounting methods, see C. S. Orwin's *Farming Costs*, and for a critical discussion of principles, J. S. King's *Cost Accounting applied to Agriculture.*

[2] *The Cost of Grazing*, University of Leeds, Bulletin No. 144.

Carrying capacity was measured by equating the various classes of stock as follows:—

1 Calf	= 2 sheep
1 Heifer or store beast	= 4 to 5 sheep
1 Cow or fattening bullock	= 6 sheep
1 Horse	= 6 sheep

On this basis, and assuming a grazing season of twenty-two weeks' full keep, the average carrying capacity was 1 cow equivalent to 1·45 acres. The average cost per cow equivalent was thus £3, 9s. 10d. per season, or 3s. 2d. per week, or nearly 5½d. per day. Assuming that the grass provided a ration of 11 lb. starch equivalent per day (*i.e.*, a two-gallon ration for a 9 cwt. cow) the cost per lb. of starch equivalent was a halfpenny. The cheapness of grass in comparison to other foods is obvious; linseed cake at £11 per ton costs just three times as much.

Costs on individual farms show a wide range of variation. In the following table four individual accounts for the years 1922 and 1923 are placed side by side with the general average for those years:—

Grazing Costs, 1922-1923.

	Average (40 Farms).	Farm H.	Farm C.	Farm CN.	Farm F.
Rent	£1 8 7	£3 10 4	£1 8 3	£0 13 6	£1 5 10
Rates	0 8 0	2 1 11	0 10 11	0 4 2	0 15 9
Manures and lime	0 3 6	0 13 9	0 16 8	0 14 8	0 5 5
Incidentals	0 13 5	1 0 6	2 11 1	0 6 2	0 13 2
Man labour	0 5 3	0 12 4	0 10 2	0 4 9	0 9 8
Horse labour	0 2 9	0 5 6	0 10 0	0 0 10	0 2 10
Total per acre	£3 1 6	£8 4 4	£6 7 1	£2 4 1	£3 12 8
Acres per cow equivalent	1·40	0·70	0·83	1·28	3·3
Acres per cow per year	£4 6 2	£5 14 11	£5 5 10	£2 16 0	£12 3 7
Cost per cow per week	£0 3 11	£0 5 3	£0 4 9	£0 2 6	£0 11 1

Farm H, a grassland small holding of 16 acres, is well managed and heavily stocked. The landlord is receiving a return of only 2 per cent. on his investment, yet the farm is seriously overburdened with rent. Its situation in an industrial area accounts for the high rates, and gives a compensating advantage in the form of a retail market. The essential cause of the high cost of grazing is that the land is overcapitalised on the landlord's side. The grassland on farm C is described as being in magnificent condition, highly productive, and fully stocked. The fault in the management is excessive expenditure on non-essentials—on roads, fences, gates, and everything that goes to make a "model" farm. The very low rent of farm CN, in relation to its carrying capacity, is accounted for by the fact that the drainage system was in a precarious condition and the holding was considered to be a risky one. Adequate manuring and full stocking were doing their part to keep down costs. The grassland on farm F is carrying less than half the normal quantity of stock, because it has seriously deteriorated in quality owing to lack of lime and phosphates.

II.—Sugar Beet Costs.

The cost of production of sugar beet has been recently a matter of special interest in view of the situation in the industry. A theoretical calculation for a medium soil might be somewhat as follows. (Man labour is taken at a flat rate of 6s. per day and horse labour at 4s. per day.)

Rent		£1 10 0
Rates		0 6 0
Horse and manurial labour :—		
Carting and spreading dung—10 tons per acre	£1 0 0	
Ploughing (⅔ acre per day)	1 1 0	
Cultivating three times at 2s. 8d. (5 acres per day)	0 8 0	
Carry forward	£2 9 0	£1 16 0

Brought forward			£2	9	0	£1 16 0
Harrowing three times at 1s. 2d. (12 acres per day)			0	3	6	
Rolling two times at 1s. 2d. (12 acres per day)			0	2	4	
Application of artificials			0	2	0	
Drilling			0	2	0	
Harrowing and rolling			0	2	4	
Singling ($\frac{1}{6}$ acre per day)			1	16	0	
Horse hoeing three times at 3s. 6d.			0	10	6	
Hand hoeing ($\frac{1}{3}$ acre per day)			0	18	0	
Lifting (with beet lifter $1\frac{1}{3}$ acres per day)			0	10	6	
Pulling, topping, and loading ($\frac{1}{8}$ acre per day)			2	8	0	
Haulage to station—12 tons gross at 2s. per ton			1	4	0	
						10 8 2
Manures :—						
10 tons dung at 8s. (half value)		£2	0	0		
4 cwt. superphosphate at 3s. 6d.		0	14	0		
2 „ 30 per cent. potash salts at 5s.		0	10	0		
1 cwt. sulphate of ammonia		0	11	0		
$1\frac{1}{2}$ „ nitrate of soda at 12s.		0	18	0		
						4 13 0
Seed, 16 lb. at 8d.						0 10 8
Depreciation on implements and general overhead charges						1 10 0
Total						£18 17 10
Deduct for beneficial cultivations						1 10 0
Net cost per acre on rail[1]						£17 7 10
Add railway carriage, 12 tons gross weight at 5s.						3 0 0
Cost per acre delivered at factory						£20 7 10
Cost per ton washed weight (tare, 16 per cent. ; net yield, 10 tons per acre)						£2 0 9

Actual costs collected and published by Bridges and

[1] No allowance is made for the value of tops, or for the preferential price for beet pulp.

Dixey for seasons 1924 (34 farms) and 1925 (45 farms) gave the following averages :—

	1924.	1925.
Rent and rates	£2 0 6	£1 16 11
Horse and manual labour	11 9 10	11 11 9
Dung (total cost)	2 4 3	1 10 1
Artificial manures	3 8 10	2 11 1
Seed	0 8 2	0 8 9
Miscellaneous	2 0 8	1 1 11
Gross cost per acre at farm	£21 12 3	£19 0 6
Transport (30 miles)	2 10 8	2 14 10
Gross cost at factory	£24 2 11	£21 15 4
Net value of tillages and manurial residues	1 16 5	3 0 4
Net cost per acre delivered at factory	£22 6 6	£18 15 0
Yield (washed weight)	10·20 tons	8·81 tons
Cost per ton delivered	£2 3 9	£2 2 7
Sugar content	16·6	17·2

A classification of individual costs per ton for 1925 gave the following distribution :—

20s. to 30s.	11 farms
30s. „ 40s.	20 „
40s. „ 50s.	9 „
50s. „ 60s.	5 „
60s. „ 80s.	4 „
80s. „ 100s.	2 „

The few very high costs are attributable to partial failures. The following are some of the more important conclusions embodied in the report :—

(1) Where the yield was under 8 tons of washed beet per acre fully 75 per cent. of farms produced the crop at a loss. Where the yield was over 8 tons, 70 per cent. of farms made a profit.

(2) In 1925 the heavier soils, in spite of higher costs per acre, produced, on account of the higher yields, more profit than medium soils; medium soils in turn gave a higher profit per acre than light soils.

(3) Farms in the eastern counties made far higher profits than those in the Midlands. This was partly accounted for

by proximity to factories, but quite largely by the higher yields and higher sugar contents obtained.

(4) The largest differences in labour costs arose in connection with singling and lifting. Low singling costs depended partly on good preparatory cultivation and partly on the efficiency of the labour. Lifting costs depended partly on the texture of the land but largely too on the condition of the soil at the time of lifting.

III.—Costs of Milk Production.

The following is an example of the average cost of milk production. The figures are those of Dr Ruston for 31 Yorkshire farms carrying 644 cows during the year 1923-1924.

Cost per Cow per Annum.

		Percentage of total costs.
Grazing	£3 7 0	9·6
Forage crops	1 4 3	3·5
Hay	3 8 5	9·8
Straw	1 5 1	3·6
Roots	4 5 8	12·3
Concentrates	9 11 9	27·6
Total food	£23 2 2	66·4
Depreciation	3 1 2	8·5
Sundries	2 17 10	8·3
Labour	9 3 4	26·0
Gross cost	£38 4 6	109·2
Less value of manure	2 13 9	7·7
Less value of calves	0 10 5	1·5
	£35 0 4	100·0

Mean yield, 581 gallons.
Mean cost per gallon, 1s. 2½d.

Since food costs in this calculation constitute two-thirds of the total, it is obviously important to examine these in detail. Let us assume that grazing costs 6d. per day, hay 60s. per ton, mangels and swedes 16s. per ton, and balanced concentrates for production £10 per ton. Then the cost of maintaining a cow of 11 cwt. live weight producing an

average yield of 2 gallons per day (730 gallons per annum) would, with accurate rationing, be as follows:—

Summer—22 weeks' grazing at 3s. 6d.		£3 17 0
Winter 30 weeks	14 lb. hay per day = 26 cwt. at 3s.	3 18 0
	40 lb. mangels and swedes = $3\frac{3}{4}$ tons at 16s.	3 0 0
	7 lb. concentrates = 13 cwt. at 10s.	6 10 0
Additional concentrates during dry period, 2 cwt.		1 0 0
Total food cost		£18 5 0

The food cost per gallon would thus be £18, 5s. ÷ 730 or 6d., neglecting manurial values.

Theoretically, apart from the prices charged for the food, the only source of variation in food costs would be the yield. Assuming exact rationing, the cost per gallon for various yields would be—

400 gallons	7·9 pence
500 „	7·1 „
600 „	6·5 „
700 „	6·1 „
800 „	5·8 „
900 „	5·6 „

The following actual figures for yields and food costs have been published by Wyllie and by the Oxford Economic Research Institute:—

Wyllie (*Kent, Surrey, and Sussex*, 1924-1925).

Farm Number.	Yield Gallons.	Food Cost per Gallon.
4	631	12·47 pence
21	601	6·69 „
31	758	9·68 „
33	482	6·80 „
41	800	9·21 „
44	593	8·91 „
5	874	8·32 „

Oxford Institute (*Oxford, Wiltshire, Northants, etc.*)

Farm Number.	Yield Gallons.	Food Cost per Gallon.
2	401	10·61 pence
4	464	10·83 „
8	579	10·22 „
5	637	6·62 „
3	700	5·97 „
6	830	4·77 „

It appears from these figures that yield is only one, and perhaps not the most important, factor governing the cost of production. What the others are will appear from a more detailed comparison of costs on two of Wyllie's farms.

	Farm 4.	Farm 33.
Yield	631	482
Food cost per gallon	12·47d.	6·80d.
Cost of production of mangels per ton	41s. 8d.	13s.
„ „ hay per ton	66s. 1d.	61s. 4d.
Cost of grazing per acre	41s. 9d.	34s. 6d.
„ per cow	71s. 11d.	35s. 3d.
Cost of purchased foods, per 100 lb. starch equivalent	14s. 11d.	13s. 3d.
Starch equivalent fed, gross, excluding grazing and green food per cow	3982 lb.	2665 lb.
„ per gallon	6·31 lb.	5·53 lb.

Perhaps the greatest single difference brought out in this comparison is that in the cost of production of home-grown foods. One would therefore be driven back to an examination of the efficiency of crop production and grassland management on the two farms. Secondly, the purchases of concentrates were made more cheaply on farm 33 than on farm 4. Thirdly, the cattle on farm 4 were overfed.

Next to food the largest element of milk costs is labour. An exceptionally high figure, of the order of £15 or £20 per cow, will generally indicate inefficient labour organisation; on the other hand, an exceptionally low figure may only mean that the milk is being produced without due regard to hygienic considerations.

APPENDIX

Table I.

NUTRIENTS REMOVED FROM SOIL BY CROPS

(In lb. per acre per annum).

	Weight.	Nitrogen.	Tri-calcic Phosphate.	Potash.
Wheat . . .	18 cwt.	35·2	33·1	9·9
Barley . . .	18 „	31·5	31·4	8·7
Oats . . .	18 „	38·5	30·2	9·7
Beans . . .	18 „	82·0	53·0	25·9
Hay . . .	1½ tons	49·0	26·8	50·9
Clover . . .	2 „	102·0	54·3	83·4
Cabbages . .	25 „	168·0	126·4	55·0
Turnips . . .	17 „	63·0	48·8	108·6
Swedes . . .	14 „	70·0	36·8	63·3
Mangolds . .	22 „	87·0	74·1	222·8
Potatoes . . .	6 „	47·0	46·9	76·5

Note.—In the above table the straw, tops, shaws, etc., are left out of account.

Table II.

MANURE SOWING TABLE.

Showing the quantity of manure requisite to be sown in a certain number of yards, equal to 1 cwt. to the acre, in imperial measure, in drills from 36 to 22 inches apart.

Distance of Drill in inches apart.	Number of the Lineal Yards in the Imperial Acre.	Length of yards for lb. equal to 1 cwt. Manure.
36	4840	43
35	4978	44
34	5124	45
33	5280	47
32	5445	48
31	5620	50
30	5808	51
29	6008	53
28	6222	55
27	6453	57
26	6701	59
25	6969	62
24	7260	64
23	7575	67
22	7920	70

Example.—Suppose the drills to be 36 inches apart—1 lb. of guano to 43 yards is equal to 1 cwt. per acre; 2 lb. to 43 yards is equal to 2 cwt. per acre; and so on, every lb. for 43 yards being equal to 1 cwt. per acre.

[From the *North British Agriculturist Year Book.*

TABLE III.

COMPOSITION OF FEEDING STUFFS.

(Compiled by the Departmental Committee on the rationing of dairy cows.)

Great variations occur in the composition of any particular food, but the following data have been compiled from a number of sources, and must be considered as having reference in each case to food of average quality.

Food.	Total dry matter.	Total Constituents.								Protein equivalent. Per 100 lb.	Starch equivalent. Per 100 lb.
		Protein.	Oil.	Soluble carbohydrates.	Fibre.	Ash.	Lime (CaO).	Phosphorus (P_2O_5).	Chlorine (Cl).		
1. *Roots.*	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Lb.	Lb.
Carrots	13·0	1·2	0·2	9·3	1·4	0·9	0·09	0·11	0·04	0·6	9
Kohlrabi	12·7	2·0	0·1	8·2	1·4	1·0	0·15	0·14	0·06	0·5	8
Mangels	13·2	1·2	0·1	10·2	0·8	0·9	0·04	0·09	0·08	0·4	7
Parsnips	15·0	1·3	0·3	11·3	1·2	0·9	0·08	0·15	0·03	0·8	11
Potatoes	23·8	2·1	0·1	19·7	0·9	1·0	0·03	0·14	0·03	0·6	18
Swedes	11·5	1·3	0·2	8·1	1·2	0·7	0·05	0·09	0·02	0·7	7
Turnips	8·5	1·0	0·2	5·7	0·9	0·7	0·09	0·10	0·04	0·4	5
2. *Green foods.*											
Cabbage (drumhead)	11·0	1·5	0·4	5·9	2·0	1·2	0·20	0·15	0·10	0·9	7
„ (open-leaved)	15·3	2·5	0·7	8·1	2·4	1·6	0·20	0·15	0·10	1·5	9
Kale (marrow stem)	14·3	2·4	0·2	6·4	3·8	1·5	0·20	0·15	*	1·3	9
„ (thousand head)	14·8	2·5	0·3	8·7	1·7	1·6	0·20	0·15	*	1·3	9
Lucerne	24·0	4·5	0·8	9·6	6·8	2·3	0·90	0·20	*	2·4	9
Pasture grass	20·0	3·5	0·8	9·7	4·0	2·0	0·25	0·19	0·42	2·1	11
Silage, vetch and oats (green fruity)	27·3	3·4	1·2	12·5	8·0	2·2	0·26	0·14	0·09	1·6	13
Silage, sunflower	18·9	2·3	1·0	9·3	3·9	2·4	*	*	*	1·5	7
Sugar beet tops and leaves	19·5	2·4	0·4	8·3	3·0	5·4	1·50	1·00	*	1·3	9
Vetches	17·5	3·2	0·5	7·2	5·1	1·5	0·50	0·15	0·04	1·8	8

3. *Hay.*											
Clover	83·5	13·5	2·9	37·1	24·0	6·0	1·20	0·45	0·06	7·0	32
Lucerne	83·5	14·2	2·6	29·2	29·5	8·0	2·52	0·65	*	7·9	24
Meadow, poor	85·7	7·5	1·5	38·2	33·5	5·0	1·00	0·40	*	2·9	19
„ medium	85·7	9·7	2·5	41·0	26·3	6·2	1·00	0·40	*	4·6	31
„ very good	84·0	13·5	3·0	40·5	19·3	7·7	1·00	0·40	*	7·8	40
Seeds	86·0	12·0	2·8	37·4	27·5	6·3	2·00	0·60	*	4·9	24
4. *Straws.*											
Barley	86·0	3·3	1·8	42·4	33·9	4·6	0·50	0·20	0·35	0·7	19
Bean	86·0	4·5	0·8	33·0	43·1	4·6	1·20	0·29	*	1·7	19
Oat	86·0	2·9	1·9	42·4	33·9	4·9	0·29	0·23	0·28	0·9	17
Pea	86·0	9·2	1·6	36·0	33·4	5·8	1·59	0·35	*	3·8	16
Wheat	86·0	2·1	1·3	40·7	36·6	5·3	0·37	0·22	0·17	0·1	11
5. *Grains and Seeds.*											
Barley	85·1	8·6	1·5	67·9	4·5	2·6	0·05	0·77	0·02	6·2	71
Beans	85·7	25·4	1·5	48·5	7·1	3·2	0·16	1·21	0·05	20·0	66
Buckwheat	85·9	11·3	2·6	54·8	14·4	2·8	0·12	1·33	0·04	8·0	53
Butterbeans (haricot)	89·2	23·6	1·1	56·4	3·7	4·4	*	*	*	15·0	68
Dari	88·9	9·6	3·8	71·2	1·9	2·4	*	*	*	7·2	74
Gram	89·0	23·4	1·1	54·3	5·1	5·1	*	*	*	15·0	71
Lentils	86·0	25·5	1·9	52·2	3·4	3·0	0·15	1·00	0·05	20·0	70
Linseed	92·8	24·2	36·5	22·9	5·5	3·8	0·30	1·40	0·86	19·0	119
Locust beans, pods	85·0	5·8	1·3	69·0	6·4	2·5	0·54	0·19	0·11	3·6	71
Maize	87·0	9·9	4·4	69·2	2·2	1·3	0·01	0·63	0·0001	6·8	81
Millet	87·5	10·6	3·9	61·1	8·1	3·8	0·02	0·75	0·02	7·7	59
Oats	86·7	10·3	4·8	58·2	10·3	3·1	0·12	0·78	0·05	7·6	60
Peas	86·0	22·5	1·6	53·7	5·4	2·8	0·12	0·90	0·04	18·0	69
Rye	86·6	11·5	1·7	69·5	1·9	2·0	0·07	0·94	0·02	9·1	72
Soya beans	90·0	33·2	17·5	30·5	4·1	4·7	0·20	1·20	0·01	28·0	79
Vetch seed	86·7	26·0	1·7	49·8	6·0	3·2	*	*	*	21·0	70
Wheat	86·6	12·1	1·9	69·0	1·9	1·7	0·06	0·93	0·06	9·6	72

* Information not available.

TABLE III.—COMPOSITION OF FEEDING STUFFS—*continued.*

FOOD.	Total dry matter.	TOTAL CONSTITUENTS.								Protein equivalent. Per 100 lb.	Starch equivalent. Per 100 lb.
		Protein.	Oil.	Soluble carbohydrates.	Fibre.	Ash.	Lime (CaO).	Phosphorus (P_2O_5).	Chlorine (Cl).		
6. *Oil Cakes and Meals.*	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Lb.	Lb.
Cocoanut cake	88·6	20·7	9·9	41·4	11·2	5·4	0·50	1·50	*	**16·0**	**79**
Cotton cake, Bombay	87·7	20·2	4·8	35·2	21·7	5·8	*	*	*	**15·0**	**40**
„ Egyptian	87·9	23·0	5·5	32·4	21·2	5·8	*	*	*	**17·0**	**42**
„ dec.	90·2	40·2	9·9	25·9	7·6	6·6	0·34	2·78	0·03	**34·0**	**71**
Cotton seed meal	91·3	42·1	10·9	24·9	7·4	6·0	0·34	2·78	0·03	**35·0**	**74**
Ground nut cake, dec.	89·7	46·8	7·5	23·2	6·4	5·8	*	*	*	**41·0**	**73**
„ „ undec.	89·7	30·2	9·1	21·8	22·9	5·7	*	*	*	**27·0**	**57**
Ground nut meal, undec. ext.	92·4	31·8	1·9	29·1	25·3	4·3	0·10	0·97	*	**29·0**	**44**
Linseed cake	88·8	29·5	9·5	35·5	9·1	5·2	0·52	1·79	0·05	**25·0**	**74**
Palm kernel cake and meal	89·0	18·8	7·7	45·3	13·4	3·8	0·30	1·10	*	**17·0**	**75**
„ meal, ext.	90·0	19·0	2·0	49·0	16·0	4·0	0·30	1·20	*	**17·0**	**71**
Sesame cake	90·7	44·5	11·9	20·9	4·5	8·9	*	*	*	**39·0**	**73**
Soya bean cake	85·5	42·4	7·0	25·8	5·0	5·3	0·30	2·20	*	**36·0**	**69**
„ meal, ext.	88·7	44·7	1·5	31·9	5·1	5·5	0·30	2·30	*	**38·0**	**64**
Sunflower cake, undec.	92·9	19·1	7·4	28·9	30·0	7·5	0·54	2·15	*	**16·0**	**50**
„ meal, ext.	92·9	19·1	2·0	32·3	32·0	7·5	0·54	2·15	*	**16·0**	**42**
Proprietary compound cakes and meals	88·0	...	...	...	...	...	...	...	...	...	**64**
	(The analyses vary considerably, but, in respect of the more generally known cakes and meals, it is safe to assume that 75 per cent. of the albuminoids are digestible.)										
7. *Manufactured and By-Products.*											
Barley-brewers' grains, wet	29·7	7·0	2·4	13·1	5·9	1·3	0·10	0·40	0·03	**5·0**	**17**
„ „ „ dried	90·2	19·1	6·6	44·5	16·4	3·5	0·30	1·20	0·06	**13·0**	**49**

Barley-distillers' grains, wet	26·2	8·4	3·0	10·4	3·6	0·8	0·10	0·40	*	6·0	16
" " " dried	92·0	27·7	11·6	40·8	10·1	1·8	0·40	1·50	"	19·0	57
" malt culms	90·0	24·4	2·0	42·4	14·0	7·2	0·19	1·82	0·36	16·0	43
Fish meal	87·0	55·6	4·4	2·1	...	24·9	10·5	6·30	0·60	48·0	53
Hominy chop	89·9	10·6	8·0	64·3	4·4	2·6	*	*	*	6·5	78
Maize, flaked	88·0	10·3	1·9	74·4	0·6	0·8	0·01	0·63	0·0001	8·6	83
" germ meal (dry process)	89·3	13·0	13·5	55·1	4·1	3·6	0·10	0·85	*	10·0	85
" germ meal (wet process)	90·0	21·0	11·5	48·5	6·5	2·5	0·10	0·85	*	16·0	78
" gluten feed	89·6	23·5	3·4	56·7	3·5	2·5	0·10	0·70	0·04	19·0	76
Meat meal	89·2	72·2	13·2	...	...	3·8	0·40	0·70	*	65·0	91
Middlings, fine	86·7	17·0	4·2	60·8	2·3	2·4	0·07	1·50	0·001	12·0	69
" coarse	86·0	15·8	4·9	56·8	4·9	3·6	0·10	2·60	*	11·0	58
Rice meal or bran	91·1	12·9	13·7	49·5	6·4	8·6	0·10	2·60	*	7·0	72
Sugar beet slices, dry	88·8	8·1	0·6	58·5	17·6	4·0	0·90	0·24	0·04	3·8	51
Treacle or molasses	74·2	3·1	...	64·7	...	6·4	0·31	0·05	0·32	2·7	51
Wheat bran	87·0	15·1	3·8	52·8	9·5	5·8	0·16	2·63	0·09	10·0	42
Yeast, dried	95·7	48·5	0·5	35·5	0·5	10·7	0·30	5·00	0·03	41·0	67
Sugar foods	The feeding value should be interpreted on the lines of the analyses given for sugar beet slices.										

8. *Milk, etc.*

Milk-cow (whole)	12·5	3·5	3·75	4·75	...	0·7	0·15	0·2	0·1	3·4	17
" " (skim)	10·0	3·5	0·75	5·0	...	0·7	0·15	0·2	0·1	3·4	10
" " (separated)	9·0	3·5	0·1	5·0	...	0·7	0·15	0·2	0·1	3·5	8
Whey	7·0	1·0	0·25	5·0	...	0·5	0·1	0·1	0·1	0·75	6

* Information not available.

TABLE IV.

APPROXIMATE LIVE WEIGHTS OF COMMERCIAL ANIMALS.

(*Live Weights show great Variations according to Breed and Feeding.*)

CATTLE.

(1) *Young Stock.*

Age in Months.	Beef Steer (full growth with fattening).	Beef Steer (full growth without fattening).	Smaller Dairy Type (Heifer).
0	80	80	70
3	200	170	150
6	400	350	220
9	560	480	290
12	700	600	360
15	830	720	430
18	950	840	510
21	1080	950	580
24	1200	1060	660
27	...	1170	750
30	...	...	850

(2) *Mature Animals (in breeding condition).*

Cows.			Bulls.		
Smaller Dairy Breeds.	Larger Dairy Breeds.	Average Beef Breeds.	Smaller Dairy Breeds.	Larger Dairy Breeds.	Average Beef Breeds.
1000	1250	1350	1250	1600	1800

SHEEP.

(1) *Young Stock.*

Age in Months.	Large Lowland (for sale as Fat Lambs).	Large Lowland (for sale as Tegs).	Medium Breeds and Cross-breds (for sale as Tegs).	Small Upland Breeds.
0	10	10	8	5
1	30	25	18	12
2	50	41	32	20
3	70	58	45	28
4	90	75	57	38
5	...	90	67	46
6	...	105	76	53
7	...	120	86	62
8	...	...	95	70
9	...	...	104	80
12	...	...	...	100

TABLE IV.—*continued.*

(2) *Mature Sheep (in breeding condition).*

Ewes.			Rams.		
Small Upland Breeds.	Medium Breeds and Crosses.	Large Lowland Breeds.	Small Upland Breeds.	Medium Breeds and Crosses.	Large Lowland Breeds.
110	150	200	150	220	280

PIGS.

(1) *Young Stock.*

Age in Months.	Pork Type.	Bacon Type.	Young Breeding Stock
0	3	3	3
1	14	14	14
2	32	32	32
3	55	50	42
4	85	80	67
5	120	115	97
6	...	155	130
7	...	200	165
8	...	245	200
9	...	...	230
12	...	...	280

(2) *Mature Pigs (in breeding condition).*

Sows.		Boars.	
Small Breeds.	Large Breeds.	Small Breeds.	Large Breeds.
350	450	450	600

HORSES.

Age in Months.	Draft Colt.
0	200
3	500
6	700
12	900
18	1150
24	1300
30	1400

TABLE IV.—*continued.*

Mature Horses (in breeding condition).

Cab Horse.	Farm Horses.			Draft Stallions.
	Small.	Medium.	Large.	
1000	1200	1400	1700	1900

V.—BUTTER AND CHEESE DATA.

To Estimate the Yield of Butter from Milk or Cream.

The yield of butter from milk or cream depends mostly on (*a*) the percentage of fat in the milk or cream, and (*b*) the percentage of water in the butter.

$$\frac{\text{The percentage of fat in the milk or cream} \times 100}{\text{The percentage of fat in the butter}} = \text{the percentage yield of butter.}$$

E.g.—How much butter may be expected from 14 gallons of milk containing 3·5 per cent. of butter fat?

$$\frac{3{\cdot}4\ (3{\cdot}5 - 0{\cdot}1 \text{ per cent., being allowance for losses in separating and churning}) \times 100}{85 \text{ (average percentage of fat in butter)}}$$

$$= \text{percentage yield of butter} = 4.$$

But lb. of milk available = 14 × 10·3 (average weight of gallon of milk).
= 144·2 lb.

144·2 lb. at 4 per cent. = 5·8 lb.

To Estimate the Yield of Hard-Pressed Cheese.

The fat percentage in the milk × the factor 2·7 = the percentage yield of cheese.

E.g.—How much Cheddar cheese may be expected from 300 gallons of milk containing 3·7 per cent. of butter fat?

300 gallons × 10·3 (average weight of a gallon of milk) = 3090 lb. of milk available.

Yield of cheese from 100 lb. of milk = 3·7 × 2·7 lb.

" " 3090 " $= \frac{3{\cdot}7 \times 2{\cdot}7 \times 3090}{100}$ lb.

= 309 lb.

Note.—The percentage of water left in cheese can be varied in the manufacturing process, and has a very considerable influence on the yield.

TABLE VI.—LABOUR.

Operation.	Width.	Per 8-hour Day.
		Acres.
Ploughing lea	8 in.	$\frac{2}{3}$
„ stubble	9 in.	$\frac{3}{4}$
Cross-ploughing	10 in.	1
Tractor ploughing	2 furrows	$2\frac{1}{2}$
Ridging	27 in.	3
Harrowing	9 ft.	14
Cultivating	7 ft. 6 in.	10
Grubbing	4 ft. 6 in.	6
Rolling, 2-horse	9 ft.	12
„ 1-horse	6 ft.	8
Disc harrowing	6 ft. 6 in.	7
Horse-hoeing, 1-horse	Single drill	$3\frac{1}{2}$
3-row horse-hoeing, 2-horse	6 ft. 9 in.	9
Drill grubbing, 2-horse	Single drill	3
Potato lifting (full set of 20 lifters)	...	3
Singling roots	9 in.	$\frac{1}{8}$
Lifting roots	...	$\frac{1}{3}$
Hand-hoeing roots	...	$\frac{1}{2}$
Cutting with binder	5 ft.	6
„ „ mower	5 ft.	8
Drilling seed	8 ft.	10
Broadcasting by hand	...	18
„ „ grass seed machine	$16\frac{1}{2}$ ft.	18
Swath-turning	2 swaths	16
Stooking 5 qr. crop of wheat	...	$2\frac{1}{2}$
Sowing fertilisers with machine	...	10
Planting potatoes (set of 5 planters and lad carting seed)	...	$3\frac{1}{2}$
Sowing turnips	2 rows	8
Cutting with scythe	...	$\frac{4}{5}$
		Tons.
Carting dung $\frac{1}{3}$ mile to heaps in field (3 carts and helper to fill)	...	24
Carting turnips $\frac{1}{3}$ mile from field to steading (3 carts and helper to fill)	...	24
		Cwt.
Threshing wheat and oats	...	240
„ barley	...	280
		Sheep.
Clipping short-wool sheep	...	16
„ half-bred „	...	30-40
„ Blackface „	...	80-100
		Cows (per hour).
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